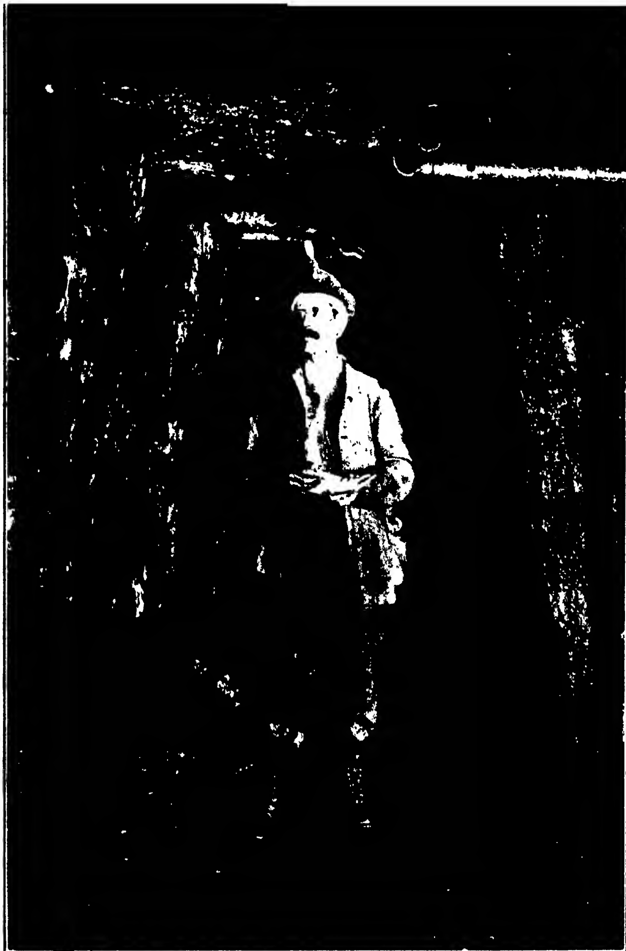
THE ELEMENTS OF

MINING AND QUARRYING.



SIR CLEMENT LE NEVE FOSTER.

From a photograph taken in Foxdale Mine, Isle of Man, June 1897, by Mr G. J. Williams, H.M. Inspector of Mines.

THE ELEMENTS OF

MINING AND QUARRYING.

BY

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WHICH IS INCORPORATED THE ROYAL SCHOOL OF MINES;
LATELY ONE OF H.M. INSPECTORS OF MINES.

FOURTH EDITION.

With Frontispiece and nearly 300 Illustrations.

LONDON:
CHARLES GRIFFIN & COMPANY, LIMITED
EXETER STREET, STRAND, W.C. 2.
1919.

NOTE TO THE THIRD EDITION.

Prof. Sir C. Le Neve Foster's larger work, *Ore and Stone Mining*, was described on publication as "epoch-making," and immediately took front rank for advanced students and practical men. This smaller work was prepared at the suggestion of the Publishers, to meet the needs of those who did not require the long and minute description essential to the larger book, and it was the last and most mature work of the distinguished author, who was acknowledged to be the greatest authority on mechanical, metallurgical, geological, and legislative aspects of mining and quarrying. For accuracy of teaching, for brevity and comprehensiveness it is unequalled, and forms a thoroughly trustworthy guide, not only for the beginner but for the experienced miner, as well as directors and shareholders of mining companies who desire to obtain an authoritative, clear exposition of mining by a writer possessing singularly happy powers of exposition. This edition contains the revision made for the Second Edition by Prof. S. Herbert Cox, Assoc.R.S.M.

C. G. & CO. Ltd.

London, *January* 1917.

Reprinted for Fourth Edition.

PREFACE.

After devoting time and trouble to the preparation of this little work, I am not likely to be the first to decry it; but, nevertheless, I feel it my duty to warn the student who is entering upon the study of the Art of Mining that he must not depend solely upon books, and that he will never learn much about the subject unless he diligently visits mines and obtains his knowledge first-hand. I look upon a mining treatise as a guide-book. If one visits a foreign country, a 'Baedeker' or a 'Murray' is purchased, with the object of learning what places are to be visited with the greatest profit, what sights are the most attractive. In a similar manner a book on mining aids the student in acquiring information, explains points which may be obscure, and suggests subjects for inquiry, but without in any way enabling him to dispense with the knowledge which comes from seeing and doing things.

Many persons have given me aid in preparing this book, and to all of them I desire to express my gratitude. My thanks are also due to the Councils of the following Institutions for permission to make use of illustrations which have appeared in their Transactions, viz.—The Institution of Civil Engineers, the Institution of Mining and Metallurgy, the Iron and Steel Institute, and the Institution of Mining Engineers. In a similar

manner, I am indebted to the Editors of *The Engineering and Mining Journal*, New York, *Mines and Minerals*, Scranton, Pa., and *Glückauf*, Essen. My friend and former colleague Mr G. J. Williams has enabled me to embellish my pages by placing at my disposal his large collection of photographs; and, lastly, I am under obligations to my friend Mr Ware of the Home Office for kindly reading the proofs and preparing the index.

C. LE NEVE FOSTER.

ROYAL SCHOOL OF MINES,
LONDON, *November* 1903.

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THE ELEMENTS OF MINING AND QUARRYING.

INTRODUCTION.

MINING in the broadest sense of the term is the art of extracting minerals from the crust of the earth. The two principal kinds of workings for obtaining minerals are known as 'mines' and 'quarries'; but, owing to legislative enactments, these words, or their equivalents in other languages, have various meanings, and consequently it is impossible to give precise definitions which will suit all countries. In the British Isles the 'quarry' is a working open to the sky, as distinguished from the 'mine,' in which the mineral is obtained from excavations under a cover of rock. With us, therefore, it is the nature of the excavation which decides whether the working is a mine or a quarry; in some other countries, on the contrary, it is the nature of a mineral worked which settles the question. Consequently excavations which are legally 'quarries' in England may be legally 'mines' if situated in France or in some of our Colonies, and *vice versâ*. Under these circumstances it is unwise to think of separating quarrying from mining in a small elementary treatise.

Further, it is best for the elementary student to deal with the subject broadly, and not confine himself to the narrower sphere of the coal miner or the seeker for metallic ores. After mastering the general principles of his art, he can specialise later on; and when one considers that the tools employed in all kinds of mining are very similar, and that the appliances for raising the mineral to the surface and for draining and ventilating the workings are often identical, it is evident that the elementary student need not be in a hurry to devote himself exclusively to one particular branch of the profession.

In treating my subject I propose to follow what may be called the natural order.

Before beginning to work the useful minerals, the student should have some general ideas concerning the manner in which they lie in the earth's crust, the indications which lead to their discovery, and the methods of search.

The modes of excavating materials of varying hardness will naturally occupy much attention.

During the work of excavation the miner has frequently to prevent the roof and sides from falling in upon him, and the means of support have to be studied.

The arrangement of the excavations, so as to secure a cheap and safe removal of the mineral deposit, needs special consideration.

Next comes the conveyance of the mineral from the working places to the surface, the journey being most commonly performed in two stages.

The subsidiary but indispensable operations of keeping the workings free from water and supplying them with air and light are important enough to require separate chapters.

The means by which the miners reach their working places are various, and must be designed so as to save time and labour.

The mineral as brought up from the workings is frequently unfit for the market, and has to be prepared before it is sold.

Obtaining an insight into all these subjects may appear a sufficient task for the elementary student; but I think it desirable that he should go a trifle further, and from the very outset seek to acquire a little information concerning the laws regulating mining, and the diseases and accidents incidental to the miner's calling.

The student may easily recollect each separate sub-division of the subject by a single word, viz.:—

I. Occurrence.	IX. Drainage.
II. Discovery.	X. Ventilation.
III. Boring.	XI. Lighting.
IV. Excavation.	XII. Access.
V. Support.	XIII. Dressing.
VI. Exploitation.	XIV. Legislation.
VII. Haulage.	XV. Health.
VIII. Hoisting.	XVI. Accidents.

This list should be committed to memory, as the various headings serve as pigeon-holes, according to which a student may arrange his notes upon any particular mine or quarry which he visits.

CHAPTER I.

OCCURRENCE.

The principal substances which we obtain from the earth's crust are the metals and their ores, fuel, building materials, roadstone, salt, gems, abrasives, and minerals required for various chemical manufactures.

The deposits of these various substances occur in the earth's crust in various ways; for the purpose of the miner they may be conveniently classed, according to their shape, into: I. Tabular, and II. Non-tabular. The tabular deposits may then be subdivided according to their origin into two classes: (1) Beds; (2) Veins. For want of a better word the non-tabular deposits may be called (3) Masses.

The classification, therefore, stands thus:—

I. Tabular or sheet-like deposits.	1. Beds. 2. Veins.
II. Non-tabular deposits.	3. Masses.

(1) Beds or Seams.

A 'bed' or 'seam' is simply some special member of a group of stratified rocks; in other words, it has been formed as a layer at the bottom of some sea, lake, or river by the deposition of mud, sand or stones, by the evaporation of saline solutions, or by the growth of animal or vegetable organisms.

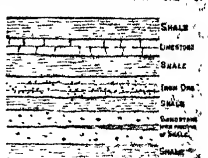


FIG. 1.—Beds of shale, sandstone, limestone, and iron ore.

A given bed may vary considerably in thickness; it may dwindle away gradually, or increase in size, or become divided into two, owing to the intercalation of a parting of valueless rock; but, in spite of such variations, a bed is much more uniform in thickness and composition than a vein.

The terms 'dip' and 'strike' are used with precisely the same meanings as are given to them by the geologist.

The stratum immediately above a bed or seam which is being worked is usually known as the 'roof,' and the stratum lying underneath it is called the 'floor' or 'pavement.'

Many of the most important mineral deposits in the world are beds containing a very small proportion of some metal, such as copper, gold, or lead, but enough, nevertheless, to make its extraction commercially profitable.

In other cases the whole of the bed is utilised, as happens with fossil fuel, or with sandstone and limestone employed for building purposes.

The thickness of the beds now being worked commercially varies between wide limits; the valuable part of the seam of copper-bearing shale which has made the Mansfeld mines so famous is only 3 to 7 in. thick, whilst beds of slate 100 ft. thick and more are common. Even with one and the same mineral, such as coal, the limits are considerable. The coal seams worked in this country vary in thickness from 1 to 30 ft., and this latter figure is exceeded on the Continent and in America. When one comes to such minerals as sandstone, limestone and chalk, one may frequently see a succession of strata several hundred feet in height forming the face of a quarry.

(2) Mineral Veins.

A 'vein' or 'lode' is a tabular body of mineral which has been formed subsequently to the rocks which enclose it.

This is very apparent in certain typical cases; *a a*, *b b*, and *c c* (fig. 2) represent beds of sandstone and limestone traversed by bands of calcite, *d d*; zinc blende, *e e*; and galena, *f f*. It is difficult to conceive that during the deposition of the calcareous matter and sand, which have now become limestone and sandstone, a deep gap existed on the sea bottom, along which were deposited the upright bands of calcite, blende and galena; on the contrary, the vein looks as if it had been formed by the growth of layers of mineral parallel to the sides of a crack or fissure in rocks which had already become hard and solid. This hypothesis is strengthened when one finds enclosed in the vein pieces of rock which evidently have been broken off from the sides. The resemblance of a vein to a filled-up fissure is often so marked, that a deposit of this kind is known in some countries as a 'cleft' (Kluft, Ger.), a more correct metaphor than our word 'vein.'

In addition to these sharply defined lodes, in which the valuable material ends off suddenly at the sides of the original crack, there are others in which the mineral sheet, as shown by the stippling in fig. 4, gradually fades into the surrounding rocks without any distinct bounding planes. Probably the fissure A B (fig. 4) furnished a channel for mineral solutions which altered the rock at its sides and so produced a sheet of ore-bearing material, C D F E. This tabular ore-body dependent upon a cleft is likewise called a vein or lode.

Instead of a single cleft, there may be a group of several cracks more or less intersecting one another, and the term 'vein' is then applied to the whole of the sheet-like body of fissured material impregnated with some valuable ore. The vein may even be a body of fault-breccia or fault-conglomerate cemented by minerals,

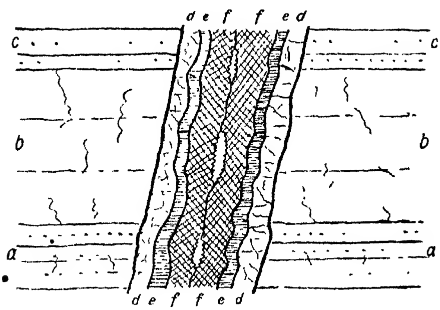


FIG. 2.—Vein of calcite, zinc blende and galena, showing banded structure.

which have been deposited in the interspaces which originally existed between the fragments, and in the cracks which traversed them.

It is frequently impossible to decide definitely whether a given deposit has been formed contemporaneously with, or subsequently to, the enclosing rocks. In some instances the valuable constituent of a bed has evidently wandered in since the deposition of the original sediment. This has certainly happened with the copper-bearing conglomerate of Lake Superior, for the native copper was not deposited at the same time as the pebbles. The same hypothesis has been offered in the case of the gold-bearing conglomerate in the Transvaal.

FIG. 3.—Vein of gold-bearing quartz, St David's Mine, Dolgelly, North Wales; from a photograph by Mr G. J. Williams, H.M. Inspector of Mines.

When the deposit can claim to be of sedimentary origin irrespective of its valuable ingredient, I consider that it is most appropriate to designate it as a 'bed' or 'seam' in spite of the later infiltration of the gold, copper, or other metal.

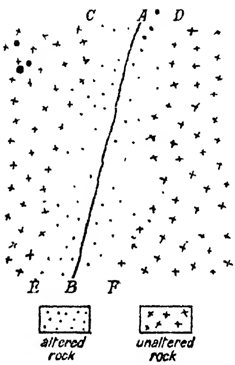


FIG. 4.—Mineral vein, consisting of altered rock adjacent to a fissure.

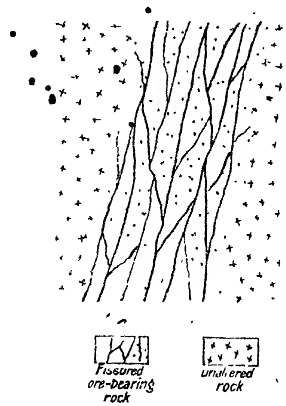
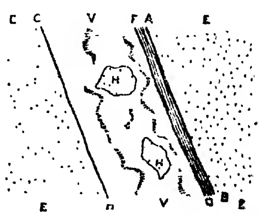


FIG. 5.—Mineral vein formed out of altered fissured rock.

Like a bed, a vein has its dip and strike; but as the dip of the vein is generally great, it is often measured from the vertical, and is then spoken of as the *underlie*, *underlay*, or *hade*. Instead of being expressed in degrees, the underlie is sometimes measured by the amount a lode plunges under cover, or away from the vertical, in a distance of one fathom measured along the dip.

The bounding planes of a vein, V V (fig. 6), are called the *walls* or *cheeks*, and they are frequently smooth or striated, showing that one side must have slid against the other. The wall above a lode is called the *hanging wall*, A B; the



Vertical Cross Section.

FIG. 6.—Mineral vein showing 'gouge' and 'horses.'

one underneath, the *foot wall*, C D. The rock surrounding and enclosing the lode is called the *country*, E E.

It is not unusual to find a layer of clay, F G, between the lode and the enclosing rocks; such a layer is called a *selvage*, *dig* or *gouge*. A large mass of the adjacent rock found enclosed in the lode is called a *horse*, H H.

The valueless components of a lode which surround the ore are often spoken of as the *veinstone* or *matrix*.

Veins are of less uniform productiveness than beds, and are rarely worth working throughout. Rich portions alternate with poor or worthless portions.

Experience shows that many conditions affect the productiveness of a mineral vein, and especially intersections with other veins, or changes in the nature of the adjacent rock. Few facts are more generally recognised than this influence of the enclosing rock upon the productiveness of a lode. A very marked case has been noticed in the Lydenburg district of the Transvaal, where the veins are worthless in greenstone and poor in dolomite; but in the sandstone they contain 1 to 3 oz. of gold per ton, and in the slate 10 to 50 oz. In the Alston Moor district, on the other hand, the lead veins are generally more productive in limestone than they are in sandstone or shale.

(3) Masses.

Lastly, we come to the non tabular deposits which are grouped under the heading 'masses.' The term is simply used for general convenience to denote deposits which are neither beds nor veins. It brings together a very heterogeneous series of mineral deposits, such as huge bosses of granite and other igneous rocks from which we obtain supplies of building stone and road metal, the diamond-bearing necks of old volcanoes in South Africa, and the irregular bodies of hæmatite. Here, too, are placed the so-called 'stockworks,' *i.e.* portions of rock so interpenetrated by a network of small veins that the whole of the material has to be excavated in order to extract the ore with profit.

Examples.

As the same mineral may be found in a bed, a vein, or a mass, the simplest plan is to classify the examples alphabetically. The mineral deposits to which I propose to refer are:—

Coal, copper ore, diamonds, iron ore, lead ore, nitrate of soda,

oil shale, petroleum, phosphate of lime, salt, slate, sulphur, tin ore, zinc ore.

Coal.—Solid fossil fuel occurs in strata of most geological ages from the Pliocene down to the Carboniferous rocks, as shown by the accompanying table.

EXAMPLES OF COAL DEPOSITS OF DIFFERENT GEOLOGICAL AGES NOW BEING WORKED.

		Geological Age.	*Locality.*
Tertiary		Pliocene.	Italy.
		Oligocene	Northern Germany.
		Eocene	Washington, U.S.A.
Secondary		Cretaceous.	British Columbia, Hanover.
		Jurassic	Sutherlandshire, Hungary, Tonkin.*
		Triassic.	Virginia and North Carolina, U.S.A., India, Queensland,† and parts of New South Wales.
		Permo-triassic (Karoo beds).	Cape Colony, Natal, Transvaal.
Palaeozoic		Permo-carboniferous.	New South Wales.†
	Carboniferous.	Coal Measures.	United Kingdom, Belgium, France, Germany, Bohemia, Spain, Pennsylvania.
		Millstone Grit.	Northern Britain.
		Carboniferous Limestone.	,, ,,
		Calciferous Sandstone.	,, ,,

The Tertiary deposits are generally lignite or brown coal; in all the other cases the mineral worked is either true coal or anthracite.

In this country, and in many others, it is especially in the Coal Measures that the seams are most numerous, extensive and valuable. In England the thickness of the seams worked varies from 1 to 30 ft., though the 'Ten-yard' seam has been known to attain a total thickness of 39 ft., including 3 ft. of partings. Even this amount is occasionally considerably exceeded in other countries. A seam of coal 180 ft. thick (55 m.) is being worked in France, and brown coal beds in Germany sometimes attain the enormous thickness of 300 to 330 ft. (90 to 100 m.).

The seams of coal may consist of clean coal throughout, or may contain partings of shale (*batt, clift, bind, metal, blaes*), sandstone (*stone, post*), or iron pyrites. This last mineral is likewise found in the form of thin sheets in the natural joints running across the seams.

* Laurent, *Les Produits Coloniaux d'origine minérale*, Paris, 1903, p. 23.
† Pittman, *The Mineral Resources of New South Wales*, pp. 310 and 311.

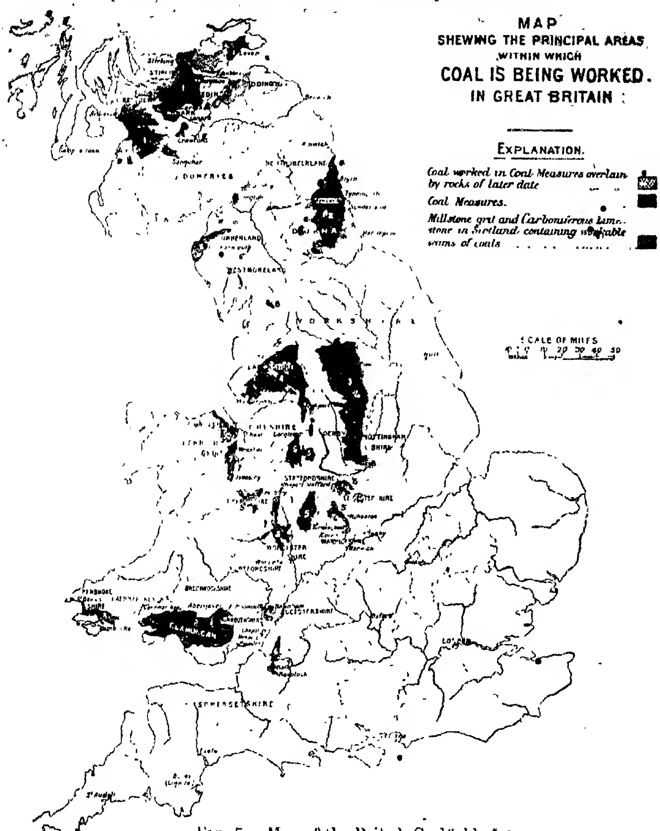


FIG 7 —Map of the British Coalfields.*

COALFIELDS.

1. Scotch coalfields —Fife, Clackmannan, Clyde Basin, Ayr, Dumfries, Sutherland, Lothians.
2. Northern coalfield.—Northumberland and Durham.
3. Yorkshire, etc, coalfield.—W. Riding Yorkshire, Derby and Notts
4. Lancashire and Cheshire coalfield.—Lancashire and Cheshire.
5. Midland coalfields.—Stafford, Worcester, Salop, Leicester and Warwick.
6. Small detached coalfields.—Cumberland and Westmorland, N Riding Yorks, Gloucester, Somerset and Devon.
7. North Wales coalfield —Flint and Denbigh.
8. South Wales coalfield.—Pembroke, Carmarthen, Glamorgan, Brecon and Monmouth.

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1897, London, 1898, p. 164.

The principal British coalfields are shown on the accompanying map.

Copper.—The most important copper mines of the world nowadays are those of Mansfeld in Germany, Rio Tinto and Tharsis in Spain, San Domingos in Portugal, and Michigan, Arizona, and Montana in the United States.

The Mansfeld district is specially interesting from the fact that the ore is found in a bed or seam of Permian age, which can be worked with profit in spite of its thinness and comparative poverty. It is a blackish, bituminous, marly shale, about 15 to 18 in. thick. The ore is usually disseminated through it in the form of fine particles (*Speise*) which impart a metallic glitter to the surface of cross-fractures. The whole of the bed is copper-bearing; but, as a rule, only the bottom three or four inches are rich enough to be worked with profit.

The famous mines of Rio Tinto, Tharsis, and San Domingos are contained in a great metalliferous belt of country, 140 miles long by 30 miles wide, stretching across the province of Huelva in Spain into Portugal. The rocks consist of slate of Upper Devonian age, often altered locally into jasper, talc schist, chiastolite schist, etc., with great intrusions of quartz and felspar-porphyries, diabase, quartz syenite, and granite. The strike of the slates is about 15° to 25° north of west, and the dip is either vertical or at a high angle to the north.

The south lode, the one most largely wrought hitherto, is sometimes as much as 450 ft. wide, and is known along the strike for a distance of about a mile, or indeed for two miles if the San Dionisio lode is considered to be an extension of it to the west. Fig. 8 is a cross section of the south lode, at Rio Tinto.

The ore consists of fine-grained compact iron pyrites with about 1 to $3\frac{3}{4}$ per cent. of copper; this metal exists in the form of copper pyrites minutely disseminated through the mass.

The copper-bearing district of Michigan lies on a long peninsula, 15 to 20 miles wide, with a north-easterly trend, which projects into Lake Superior.

The modes of occurrence of the copper may be classified as follows:—

Beds. { 1. Copper-bearing conglomerate and sandstone.
{ 2. Copper-bearing amygdaloid.

Veins.

The deposits of the first class are beds of conglomerate and sandstone impregnated with native copper. In most cases the cupriferous beds are intersected with diabase flows; but this

connection between the proximity of diabase and the presence of copper is not universal. The copper occurs as the cementing material of the pebbles and grains of sand, and also replaces the pebbles themselves, large stones several inches or even a foot in diameter being converted into the native metal. The copper has evidently been deposited from aqueous solutions. By far the greatest proportion of the Lake Superior copper is obtained from these conglomerates.

The cupriferous amygdaloids are portions of old lava flows, and are not, strictly speaking, beds as defined, though it is convenient to call them by that name.

Often they are highly altered and have lost all sign of having once been vesicular; the native copper which they contain must have found its way in long after their eruption. It is usually

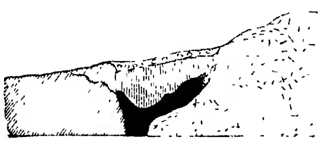


FIG. 8.—Cross section, South Lode Rio Tinto.

Index to fig. 8.

Porphyry. Slate. Pyrites.

Porphyry worked away. Slate worked away. Pyrites worked away.

Ferruginous breccia and gozzan.

very irregularly distributed, and the parts rich enough to be worked may be surrounded by much poorer or barren rock. The presence of epidote and calcite is regarded as a good indication for the proximity of copper.

As the cupriferous lava beds and conglomerates are locally called 'veins,' it is necessary to say that the real veins run in a direction at right angles to the general trend of the beds, and are almost vertical. Their usual width is from 1 to 3 ft., but it may become as much as 10, 20, and even 30 ft. They are largest and richest when they have amygdaloid or loose-textured diabase for their walls, and they become pinched up and worthless in the compact greenstone or sandstone. To a great extent they consist of altered rock, and are an instance of lodes formed

by replacement of the 'country.' According to Irving these veins were formed by copper-bearing solutions which found a path through zones of fissured rock, instead of following certain easily permeable beds. The copper is in the native state, and generally in masses of considerable size, the largest found weighing over 400 tons.

Arizona produces large quantities of the oxidised ores of copper, especially malachite and azurite, which occur in irregular masses where Palæozoic limestones and shales are in contact with intrusions of porphyry of late Cretaceous or early Tertiary age. Chalcopyrite which has escaped decay shows whence the oxidised ores have been derived.

The deposits of the Butte district, Montana, are east and west

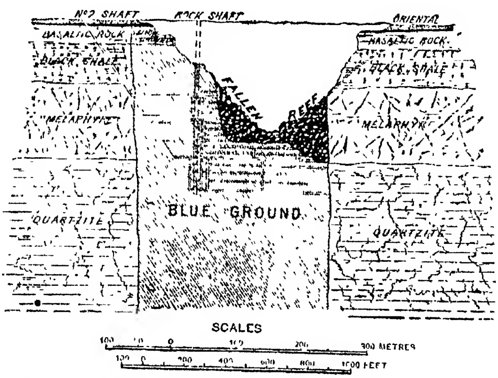


FIG. 9.—Section across De Beers diamond mine, Kimberley.

lodes in granite, usually dipping to the south. The main lode which supports the celebrated Anaconda and Parrott mines has proved productive for a distance of three miles along the strike.

Diamonds.—Kimberley is by far the most important diamond district in the world. The masses of diamond-bearing rocks may be described as huge vertical columns of round, oval, or kidney-shaped section, as shown by fig. 9. The unweathered diamond-bearing rock, locally known as 'blue ground,' or 'blue,' is a breccia, consisting of fragments of shale, basalt, diorite, and a little sandstone, cemented together by olivine rock containing diamonds and other minerals. The surrounding rocks, locally

called 'reef,' are beds of carbonaceous and pyritiferous shale lying horizontally, and sheets of basalt and melaphyre, under which comes quartzite. The melaphyre is a hard amygdaloidal rock, which has been called olivine diabase. Large detached masses of the surrounding rocks are sometimes included in the 'blue,' and are then known as 'floating reef.' The upper parts of the deposits have been decomposed by atmospheric agencies, and changed into a soft friable earth to a depth varying from 45 to 60 ft., and the colour is a yellow, instead of the slaty blue of the unweathered rock. The surrounding rocks have naturally shared in this weathering.

The diamond bearing rock appears to be the filling up of the necks or throats of old volcanoes by a mud which has come up from below.

In addition to diamonds found in a solid matrix, there are those from the Vaal river diggings. Diamonds are also found in alluvial gravel and in conglomerates in Brazil, British Guiana, India, and other localities.

Gold is so widely distributed over the earth that it will be impossible to compress into the space at my disposal anything more than a very brief summary of the principal modes of occurrence in beds, veins, and masses.

Most of the gold in the Transvaal is obtained from beds of conglomerate or pudding stone called '*banket*.' The layers of this conglomerate lie conformably among beds of sandstone, shale, clay, and quartzite. At Johannesburg the beds strike east and west and dip to the south The conglomerate consists mainly of pebbles of white quartz, and in the upper part of the workings they are cemented together by oxides of iron, sand, and clay. Below the influence of atmospheric agencies, the cementing material is found to consist largely of silvery grey micaceous matter with cubical crystals of iron pyrites, and the colour of the banket changes from red and brown to blue and bluish grey. It is quite evident that much of the ferruginous matter in the upper part of the conglomerate is derived from the decomposition of iron pyrites, and visible gold is seen in the cavities formerly occupied by crystals of that mineral. The bulk of the gold is said to exist in the cement and not in the pebbles.

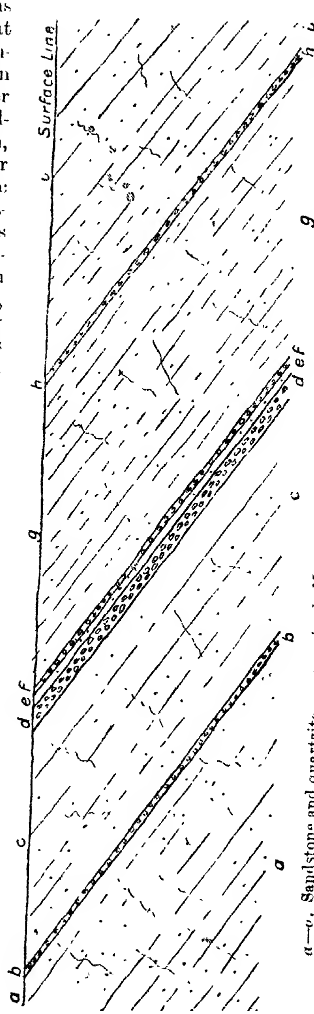
Fig. 10* is a section across part of the Langlaagte Estate (East) at Johannesburg, and shows four beds of auriferous conglomerate known respectively as the North Reef, Main Reef, the Main Reef Leader, and the South Reef.

* Copied in part from Hatch and Chalmers' *Gold Mines of the Rand*, 1895.

Auriferous veins usually consist in great part of quartz, and contain in addition iron pyrites, or some other heavy metallic sulphide, such as galena, zinc blende, copper pyrites, magnetic pyrites, stibnite or mispickel. The gold is principally in the metallic state, even when enveloped in pyrites, which is so frequently the case; but it occurs also in combination with tellurium.

The gold veins, or 'reefs,' in Victoria are found in the Upper and Lower Silurian rocks. The gold is especially associated with iron pyrites; when this decomposes a cellular honeycombed quartz is left behind, and the gold is unmasked and becomes visible in the little rusty cavities.

The peculiarities of so-called 'saddle reefs' of the Sandhurst or Bendigo goldfield, Victoria, which differ considerably from typical veins, have been very clearly explained by Mr. T. A. Rickard.*



a—a. Sandstone and quartzite.
b—b. North reef.
c—c. Sandstone and quartzite.
d—d. Main reef.
e—e. Sandstone and quartzite.
f—f. Main reef leader.
g—g. Sandstone and quartzite.
h—h. South reef.
i—i. Sandstone and quartzite.

FIG. 10.—Section across Langlaagte Estate (East).

* "The Bendigo Goldfield," *Trans. Amer. Inst. M. E.*, vol. xx. (1891), p. 463.

Coming to 'masses,' the great Treadwell mine situated on Douglas Island, Alaska, owes its existence to a mass of auriferous altered granite, 400 ft. wide and of considerable length.

At Mount Morgan, near Rockhampton, in Queensland, the auriferous deposit at the surface was a mass of brown hæmatite, sometimes stalactitic and containing a little silica, which passed gradually into a ferruginous siliceous sinter. The gold exists in great purity in a state of minute subdivision, and the metal extracted is of extreme purity, for it contains 99·7 of gold, the rest being copper, a trace of iron, and a minute trace of silver. These oxidised ores were replaced by mundic ores followed by low-grade auriferous copper ores in depth.

Iron is very largely distributed over the globe, and affords instances of many modes of occurrence, though veins of iron ore are quite overshadowed, as sources of the metal, by the yield of beds, and especially those of Jurassic age.

The most productive European deposits at the present time are: the bed of iron ore in the Cleveland district, the masses of red hæmatite in Cumberland and North Lancashire, the beds of brown hæmatite in German and French Lorraine and Luxemburg, and the beds of red and brown hæmatite and spathose ore near Bilbao, in Northern Spain.

The bed of ironstone worked in the Cleveland district is found in the Middle Lias. It is about 10 ft. thick, and most of the iron exists in the state of carbonate: much of the ore is oolitic in structure. The main seam practically furnishes all the Cleveland ore. It probably extends over an area of 350 square miles, though it cannot be profitably worked over anything like the whole of the district.

The great iron field from which France and Germany are obtaining their principal supplies of ore extends over parts of the Grand Duchy of Luxemburg, German Lorraine, and the Department of Meurthe-et-Moselle, and has an area of nearly 400 square miles. The iron-bearing strata belong to the Lower Dogger or Brown Jura (Inferior Oolite), and consist of seams of oolitic iron ore interstratified with beds of limestone, marly limestone, marl and sandy clay. The iron exists mainly in the form of hydrated oxide. It is estimated that the field contains 5000 million tons of ore *; the total annual output is about 18 million tons.

One of the great iron districts of the United States is Marquette County in Michigan. The peculiarities of its iron ore deposits

* Villain, "Le Gisement du Minerai de fer oolithique de la Lorraine," *Ann. Mines*, Dixième Série, vol. i., Paris, 1902, p. 117.

have been well described by Van Hise.* Three typical modes of occurrence are shown in figs. 11, 12 and 13; in the first two an irregular body of soft hæmatite is lying upon the so called soap-

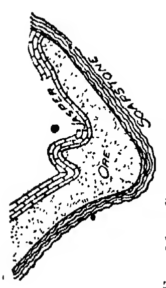


Fig. 11.—Cross section of irregular body of iron ore, Marquette district, Michigan, U.S.A.†

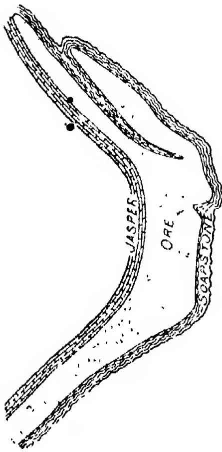


Fig. 12.—Cross section of an irregular body of iron ore, separated on one side into two parts by a tongue-like dyke: Marquette district, Michigan, U.S.A.‡

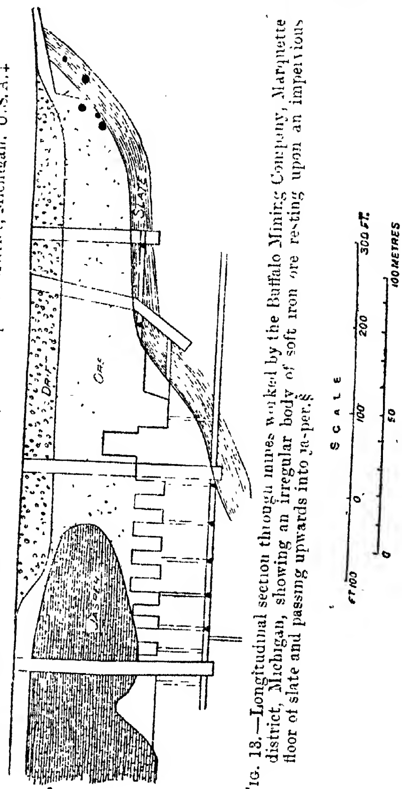


Fig. 13.—Longitudinal section through mines worked by the Buffalo Mining Company, Marquette district, Michigan, showing an irregular body of soft iron ore resting upon an impervious floor of slate and passing upwards into jasper.§

* "The Marquette Iron-bearing District of Michigan," *U.S. Geol. Survey Monographs*, xxviii., Washington, 1897.

† *Op. cit.*, Plate xxviii., fig. 4.

‡ *Op. cit.*, Plate xxviii., fig. 5.

§ *Op. cit.*, Plate xxix., fig. 3.

stone, which is the upper decomposed part of a mass of diabase (greenstone); in the last the ore reposes upon slate.

Three peculiarities of the ore bodies are specially emphasised by Van Hise: (1) The ore occurs in troughs; (2) the floor of the trough consists of an impervious, or relatively impervious rock; (3) the trough is inclined, or has a 'pitch.' He thinks that the whole of the iron-bearing rocks were once poor cherty carbonate of iron of sedimentary origin; these beds were subsequently converted into hæmatite by watery solutions, which carried away the silica and deposited iron oxide. The path of the downward-moving waters, and consequently the extent of the ore-bodies, was greatly determined by the impervious nature of the rocks now forming the floor of the deposits.

Lead.—Though lead ore is mainly wrought from veins, large supplies have been obtained from a bed. The lead-bearing sandstone at Mechernich, in Rhenish Prussia, is of Triassic age and is on an average nearly 100 ft. thick. It rests upon and is covered by conglomerate, and is often split up into two or more beds by a thick parting of conglomerate. The ore occurs in the form of little concretions of galena and grains of quartz, but these are not uniformly distributed through the sandstone.

Nitrate of Soda.—The existence of beds of nitrate of soda (cubic nitre) in the rainless regions on the West Coast of South America had been noticed for many years; but it was not until this mineral was found to be a valuable fertiliser that steps were taken to work it on a large scale. The raw nitrate of soda (*caliche*) is found in beds from 6 in. to 12 ft. thick, beneath a covering of hard conglomerate from 1 to 10 ft. thick, as shown in fig. 14.

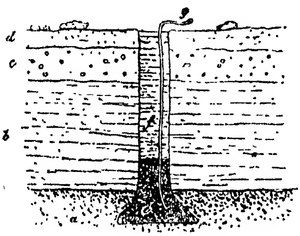


FIG. 14.—Nitrate of soda beds, Chili.
a, soft earth; *b*, 'caliche'; *c*, conglomerate; *d*, sand; *e*, charge of gunpowder; *f*, tamping; *g*, safety fuse.

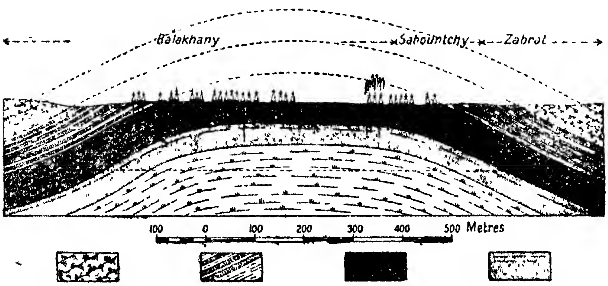
Petroleum.—Mineral oil is found in many parts of the world. The great wells near Baku* on the Caspian are bored in rocks of Lower Miocene age consisting of sand, calcareous clays, marls, and compact sandstone. Fig. 15 shows a section of the wells on the crown of a low anticlinal. The petroleum is found

* Kouchin, "Gisements de naphte de Bakou," *Guide des Excursions, VII Congrès Géologique International*, St Petersburg, 1897.

in certain beds of sand which likewise contain salt water and carburetted hydrogen gas.

The pressure of the gas may amount to 300 lbs. per square inch.

At some of the wells it is necessary to extract the petroleum by machinery, but at others it rises naturally, and occasionally with great force and in immense quantities (fig. 16). In fact, Tagieff's spouter in 1886 actually threw up, on the eighth day after oil had been struck, the immense quantity of 11,000 tons, or $2\frac{3}{4}$ millions of gallons, in twenty-four hours. The flow then diminished and



Aralo-Caspian Limestone.	Horizon of water-bearing shales variously coloured, covering the oil-bearing horizon, which contains in places petroleum with specific gravity of ·820 to ·840.	Productive horizon containing an abundance of petroleum with specific gravity of ·865 to ·875.	Horizon of water-bearing sand and clay underlying the productive horizon, and containing petroleum with specific gravity of ·885 to ·920.

FIG. 15.—Section across oil district near Baku.

was got under control by the engineers, and reduced to a quarter of a million gallons a day.

The strata which yield oil in Pennsylvania and New York belong to the Devonian and Carboniferous periods. They are beds of sand and sandstone, sometimes coarse-grained, and may yield gas as well as oil. In Ohio, the two chief sources of oil are the Trenton Limestone (Lower Silurian) and the Berea Grit near the base of the Carboniferous rocks.

Phosphate of Lime.—Deposits of phosphate of lime are found in

rocks of all ages, from the Laurentian to the recent period. The Laurentian rocks are the home of the apatite of Canada. The

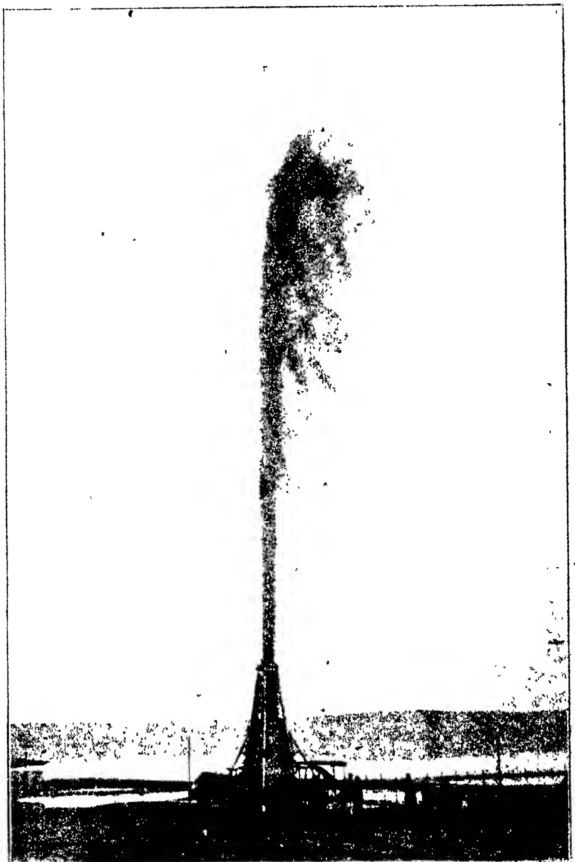


FIG. 16 -- Spouting Oil Well, Baku.

Reproduced by permission, from a photograph by Mishon, of Baku.

principal mines are in the county of Ottawa, and the mineral

occurs mainly in pyroxenite, sometimes as a contemporaneous bed and sometimes as a vein of posterior origin. The beds are from 1 ft. to 3 or 4 ft. thick, and the veins from a few inches to 8 or 10 ft. wide

Though the phosphate deposits of Bedfordshire, Buckinghamshire, and Cambridgeshire are little worked at the present time, the Cretaceous rocks have of late years yielded abundant supplies in France. In the mining district of Arras deposits of phosphate of lime are worked in three horizons: (1) At the base of the Gault, in the form of a bed of nodules, generally about 2 in. thick, and sometimes as much as 6 in. thick; (2) above the Gault, in the form of a bed of nodules 6 in. to 3 ft. 3 in. thick; (3) in the state of sand, in more or less regular funnel-shaped pockets, in the upper beds of the Chalk. This sandy phosphate is covered by a bed of clay with flints, above which comes brick earth.

The famous beds of South Carolina, besides satisfying to a great extent the wants of the United States, are able to supply large quantities of the fertiliser to other countries. The mineral occurs in the form of nodules, from the size of a pea to that of a man's head, in a bed from a few inches to $2\frac{1}{2}$ ft. thick, the average thickness being 7 to 9 in. (fig. 17). With the nodules are found bones of fish, and especially teeth of great sharks, together with teeth of the horse and other land animals. The deposits are considered to be of Post-pliocene age.

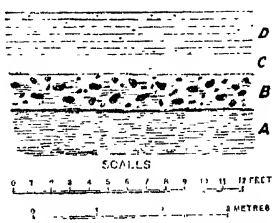


FIG. 17.—Bed of phosphatic nodules, South Carolina.*

A, Ashley marl (Eocene); B, bed of phosphatic nodules; C, ferruginous sand; D, clayey sand.

The phosphate of lime worked on Aruba and Sombrero, in the West Indies, and on Christmas Island, was originally a coral limestone. Its conversion into phosphate has been effected by the percolation of water containing phosphoric acid derived from the dung of sea-fowl. This interesting fact is made very plain by the finding of corals themselves changed into phosphate of lime.

Quicksilver.—The principal quicksilver producing mines at the present time are Almaden in Spain, Idria in Carniola, and New Almaden in California.

* Penrose, "Nature and Origin of Deposits of Phosphate of Lime," *Bull. U.S. Geol. Survey*, No. 46. Washington, 1888, p. 60.

Mr. Becker* has brought together a vast array of useful facts concerning the occurrence of quicksilver in his valuable monograph, which may be very briefly summed up as follows:—Cinnabar is found in rocks of all ages and of all descriptions, viz., conglomerate, sandstone, quartzite, limestone, shale, slate, serpentine, crystalline schist, and basic and acid volcanic rocks, but it exhibits a preference for sandstone. The quicksilver deposits are found along lines of country marked by past or present volcanic disturbances. Some cinnabar has certainly been precipitated from hot solutions brought up by volcanic springs, and it seems likely that many of the quicksilver deposits have been formed in this manner.

The famous and productive Almaden mine is situated on the northern slope of the Sierra Morena, where the rocks coming up to the surface are of Silurian and Devonian age. These rocks are beds of sandstone and quartzite interstratified with slate and a little limestone. The cinnabar occurs impregnating the sandstone; the slate is rarely, if ever, quicksilver-bearing. There are three principal deposits extending for a distance of 200 to 220 yards along the strike; the dip is almost vertical. The total useful thickness of the three beds is about 40 feet, and the mercurial rock yields on an average 10 per cent. of metal.

At Idria in Carniola, cinnabar occurs in the Triassic rocks in three ways: (1) Impregnating beds of shale, conglomerate and dolomitic breccia; (2) filling up cracks like ordinary fissure veins; (3) in irregular veins across the mass, making a stockwork.

Salt.—Sea water, salt lakes, brine springs and wells, saliferous marls, and rock salt are the sources of this very important mineral.

The extraction of salt from sea water is carried on in many countries, where the heat of the sun is sufficient to evaporate the water which has been led into shallow pools; and the industry is sometimes fostered by the traffic in salt being a Government monopoly.

Natural springs yielding brine are not uncommon, and wells are dug or bored so as to reach a brine-bearing stratum.

At Northwich, in Cheshire, there are two main beds of rock salt each from 84 to 90 ft. thick, separated by a bed of hard marl 30 to 33 ft. thick. All these beds belong to the Keuper division of the Triassic rocks. The quantity of rock salt mined in England is small, and amounts to only one-tenth of the salt obtained from brine; the latter is pumped from flooded mines, and from wells or bore-holes penetrating saliferous strata.

* "Geology of the Quicksilver Deposits of the Pacific Slope," *Monographs of the U.S. Geol. Survey*, vol. xiii., Washington, 1888, p. 7.

Silver.—All galena carries some silver, and in very many cases there is enough to make the extraction profitable. Copper ores also are frequently argentiferous; the silver in the Mansfeld cupriferous shale has already been mentioned, and the ores of the Butte district, Montana, are often rich in the precious metal. Among well-known silver mines may be mentioned those of the great Comstock lode in Nevada, Huanchaca in Bolivia, and Broken Hill in New South Wales.

The Comstock lode, usually from 20 to 60 ft. thick, and as much as several hundred feet thick in some places, consists in the main of crushed and decomposed portions of the 'country,' together with clay and quartz. The silver is found native and in the form of silver glance, polybasite, stephanite, and occasionally pyrargyrite; other minerals in the vein are quartz, iron pyrites, copper pyrites, besides oxides of iron and manganese, sulphates of calcium and magnesium, and carbonates of magnesium, calcium, lead and copper. The ore bodies are soft and irregular.

The mines of Huanchaca are situated near the town of that name in the department of Potosi, in Bolivia, at a great altitude, for the entrance of the San Leon adit is 13,500 ft. above the level of the sea. The silver lodes occur in a soft decomposed trachyte; the actual silver-bearing mineral is fahlerz, containing about 10 per cent. of the precious metal. At the famous Potosi mine also, the silver occurs in a fahlerz.

The mines at Broken Hill have been remarkable for their enormous output of silver and lead during the last few years. They are situated in the Silverton or Barrier Ranges district of New South Wales, near the western boundary of the colony. The deposit is generally spoken of as a vein or lode; the Geological Survey consider it to be a saddle lode, and others have described it as a zone of metasomatic replacement.

Slate.—About two-thirds of the Welsh slate are got from beds of Cambrian age in Carnarvonshire, and one-third from beds in the Lower Silurian rocks in Merionethshire. The quarries in the former county are mostly open, whilst in the latter the local conditions have led to the adoption of true mining, especially at Festiniog, which can boast of the most extensive underground workings for slate in the world.

Owing to peculiarities of texture, due apparently to the fineness of the sediment deposited upon the sea bottom, certain beds or sets of beds furnish a slate which can be split into very smooth sheets, as thin as $\frac{1}{16}$ inch and even less. Any set of beds worked as a whole is known locally as a 'vein,' but it does not necessarily furnish a saleable roofing material for its entire thickness. For

the fine grained slate may have beds of a coarser sediment interstratified with it, which cause irregularities in the planes of cleavage, and so give rise to inferior products. Sometimes unprofitable rock is taken away above the good slate in order to reach a firm layer, such as a bed of volcanic ash, or a 'whinstone' dyke, which can be trusted to stand as the roof of the underground chambers.

The value of a slate bed, or 'vein,' depends greatly upon the number and nature of the natural joints by which it is intersected. If they are numerous, the workings will yield blocks too small for making the larger and higher priced sizes of slates; if they are rare, more expense will be incurred in severing the material from its bed. Disturbances of the strata, resulting in fissures filled

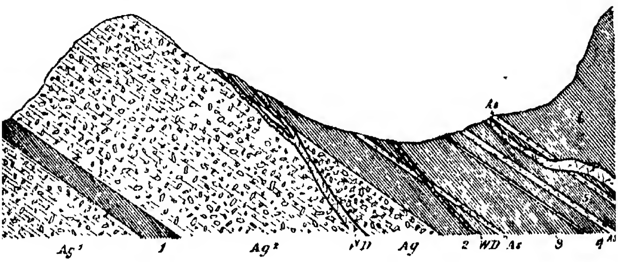


FIG. 18.—Section of the Oakley Quarries, Festiniog.*

Ag[1], Ag[2], Ag, volcanic agglomerates; 1, slate vein worked at Wrysgan and New Quarry, Diphwys; 2, new or south vein; 3, 'old vein'; 4, 2A vein; 5, back vein; 6, north vein, WD, 'whinstone' dykes (diabase); P, porphyrite; As, volcanic ash.

either mechanically with clay and broken slate, or chemically by the deposition of quartz, may render the 'vein' utterly worthless in places; but, as in the case of other bedded deposits, changes in productiveness are far less frequent than with lodes.

Sulphur.—The industrial sources of sulphur are: (1) Deposits of native sulphur, and (2) iron pyrites.

Native sulphur occurs as a product of volcanic emanations, and in sedimentary deposits. Deposits of the former kind are generally found at or near spent volcanic craters, the escape of sulphuretted hydrogen being one of their last signs of activity. Sulphur has been worked on a small scale at the famous Solfatara of Pozzuoli, near Naples, at Vulcano, one of the Lipari Islands, and in volcanic regions in various parts of the world.

* Made by Mr G. J. Williams, H.M. Inspector of Mines.

Seams or beds of sulphur occur in Sicily, Calabria, the Romagna, and other parts of Italy, and also in Croatia, Spain, and France. By far the most important beds are those of Sicily.

The accompanying section (fig. 19) shows a section of the country near Caltagirone. The letter *a* denotes beds of clay (Tortonian); *b* is tripoli (Sarmatian); *c* is the bed of sulphur-bearing limestone; *d*, white marl or marly foraminifera, called 'trubi' in Sicily; *e*, blue clay; *f*, calcareous tufa. The beds *a*, *b*, *c* are considered to belong to the Upper Miocene, whilst *d* is placed in the Lower Pliocene, and *e* and *f* in the Upper Pliocene.

The sulphur-bearing bed varies from a hard white limestone to a grey marly limestone, and from this to a marl; the sulphur itself is always in the native state, forming little globules, laminæ, or irregular lenses, varying in thickness and extent. It is often crystallised, and associated with it are celestine, gypsum, calcite and aragonite; in the clayey beds there is also bitumen, which is objectionable, as it gives a dark colour to the product obtained by liquation.

The thickness of the sulphur seams varies within very wide limits. Beds of 20 ft. thick are common, and at Lercara the stratum reaches the enormous thickness of 164 ft. Frequently there are two or three beds; at the great Sommatino mine, for instance, the deposit is 100 to 115 ft. thick, divided into six separate seams, from 6 to 25 ft. each, by partings of barren rock.

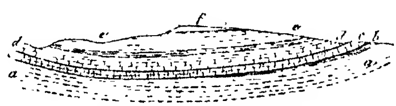


FIG. 19. Sulphur seam, near Caltagirone, Sicily.*

The yield of sulphur rock may be taken on an average at about 22 per cent., though occasional rich seams give as much as 45 per cent.

The Sicilian deposits are considered to have been formed by chemical precipitation from aqueous solutions in lakes.

After the description of the deposits of cupreous pyrites at Rio Tinto, it is quite unnecessary to say anything more about such sources of sulphur.

Tin.—Tin ore is obtained from veins, beds, and a variety of irregular deposits.

* Baldacci. *Descrizione geologica dell' Isola de Sicilia*, Rome, 1886, p. 296.

In Cornwall many of the veins in granite are due to the alteration of the rock in the neighbourhood of fissures, as has already been explained (fig. 4). The so-called *carbonas* of the St Ives district are essentially masses of stanniferous schorl rock, very irregular in shape and connected with a main lode by a cross joint or fissure. They seem to be altered granite.

Beds containing tin ore in the form of rolled pebbles and sand occur with the alluvial deposits of existing valleys in many countries. The principal Cornish 'stream works' have long been exhausted, though as lately as 1873 tin ore was raised from a bed under Restronguet Creek, a branch of Falmouth harbour; but similar alluvial beds in the Malay Peninsula are yielding more than half the world's supply of the metal. New South Wales is remarkable, not only for its recent stanniferous alluvia, but also for much older deposits, which, like the ancient gold gravels, have been preserved under a covering of basalt.

Zinc.—Zinc ore is found in veins, beds, and irregular masses. Lüderich mine, situated near Bensberg on the right bank of the Rhine, not very far from Cologne, derives large quantities of blende from a huge vein in the Devonian rocks. It may be best described as a zone or belt of broken or disturbed rock, 130 to 164 ft. (40 to 50 metres) wide, containing ore in irregular veins or masses. The ore bodies are usually lenticular in shape, dying out gradually in every direction; they sometimes consist of solid blende for a width of several yards. The minerals found in the lode are: blende, galena, copper pyrites, fahlerz, quartz, and, rarely, chalybite. The fahlerz is silver-bearing, and the blende always contains cadmium, and occasionally gallium.

Diepenlinchen mine, near Stolberg, in Prussia, is interesting not only on account of being a large producer of zinc ore, but also because some of it is derived from a great stockwork, a form of deposit less common with zinc than with tin. The stockwork consists of an oval mass of limestone full of little veins of blende; it is about 130 yards (120 metres) long from east to west, and 50 yards across from north to south.

(5) Faults.

All kinds of deposits are subject not only to irregularities dependent upon their mode of formation, such as a gradual thinning out or thickening, but to others which have taken place subsequently. Sometimes a bed, such as A B, has had a portion denuded by a current during the general period of

deposition. Such an occurrence is called a 'wash-out' or 'dumb fault' (fig. 20).

In addition to irregularities of this kind, deposits suffer from the disturbances which have taken place in the rock masses which contain them. Slight undulations of the strata are common, and when the disturbance has been greater, the beds are bent into arches and troughs, or *anticlinals* and *synclinals*. Further, the lateral pressure may have been sufficient to cause great crumpling and contortion, and, in places, to invert the order of succession. When beds are much bent, there is often a thickening in the anticlinals and synclinals, and a corresponding thinning in the connecting limbs.

A series of beds may be so folded as to produce a mass of crumpled and contorted strata very unlike the original sheet-like seams.

The disturbances of the rocks may finally cause rents accom-

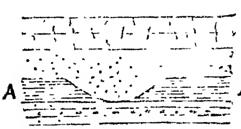


FIG. 20.—Wash-out 'fault,' or 'dumb fault.'

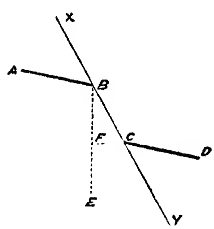


FIG. 21.—Vertical section. Throw of a fault.

panied by displacements, which are called *faults, heaves, throws,* or *slides.*

The *throw* of a fault is measured by the amount of *vertical* displacement. If X Y is a fault shifting a bed A B (fig. 19), draw B E vertical and C F at right angles to B E. Then B F is the vertical downthrow, C F represents the horizontal displacement, and B C the shift along the line of dip.

The study of faults is important, because the miner working the bed A B (fig. 21), wants to know, after reaching the fault X Y, where to find the continuation of the deposit. The rule is to follow the greater angle. The angle A B Y is greater than the angle A B X, and the missing part may be expected somewhere along the line B Y. If the miner were working from D to C, the same rule would apply, for the angle D C X is greater than D C Y.

This rule gives the direction of the throw, but affords no indication as to its amount, which may vary considerably. If the beds are distinctly marked by lithological peculiarities or by fossils, the miner can obtain useful information by driving through the fault into the rocks on the other side and endeavouring to strike some well-defined horizon.

The throw of a fault is not always the same; it varies along the strike, and finally dies away altogether.

Near a fault a bed is found often to dip more steeply, as if it had been bent before it broke.

The rule that a portion of the hanging wall side has shifted downwards along the dip of the fault is not without exceptions, especially in localities where rocks are much bent and folded. Fig. 22 shows a reversed or overlap fault.

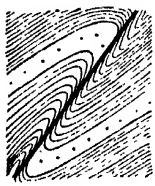


FIG. 22.—Vertical section. Reversed or overlap fault.

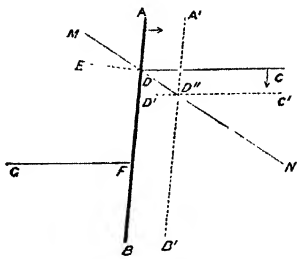


FIG. 23.—Plan. Diagram illustrating Zimmermann's rule.

As mineral veins have been formed in regions where rocks have been broken and dislocated, it is only natural to expect that they also should be affected by movements and shiftings of the earth's crust.

Owing to the fact that veins are usually highly inclined and that there is often much difficulty in deciding how the dislocated portions of the rocks fitted together before they were shifted, the vein miner speaks of faults in different terms to the bed miner. Instead of talking of *downthrows* and *upthrows*, he looks at the apparent shift sideways and calls it a *heave*.

The subject of the heaves of lodes and beds has been elucidated by Schmidt,* Zimmermann,† and others.

* *Theorie der Verschiebung älterer Gänge* Frankfort, 1810.

† *Die Wiederausrichtung verworfener Gange, Lager und Flotze.* Darmstadt and Leipsic, 1828.

Zimmermann's rule for finding the lost part of a vein on the other side of a fault is as follows:-

Lay down upon paper the line of strike of the fault (*cross-course*), and by construction ascertain the horizontal projection of the line of their intersection; from the point where the cross-course was struck by the lode, draw a line at right angles to the former and directed to its opposite wall. Notice on which side of the line of intersection this perpendicular falls, and, after cutting through the cross-course, seek the heaved part of the lode on that side.

Thus let A B (fig. 23) represent, at some given depth, the line of strike of a fault or cross-course dipping east, and C D the line of strike of a lode dipping south, and we will suppose that in driving from C to D, in a westerly direction, the fault has been met with at D. Knowing the dip of the lode and that of the fault, it is easy to lay down, on any given scale, A′ B′ and C′ D′, the lines of strike of the fault and lode respectively, at a certain depth, say at ten fathoms, below A B. The point D″, where A′ B′ and C′ D′ meet, is one point of the line of intersection. Join D and D″ and prolong on each side. The line M N represents the horizontal projection of the line of intersection of the two planes. At D erect D E at right angles to A B, and directed towards the opposite wall of the fault. As D E falls south of M N, the miner, after cutting through the fault, would drive in a southerly direction, and eventually strike the lode again at F. It will be at once understood that if the miner were following the lode from G to F, the perpendicular would lie to the north of the line of intersection, and following the rule he would drive in that direction, after cutting through the fault.

When several faults dislocate lodes one after another, very great complications may arise.

CHAPTER II.

DISCOVERY.

PAGES might be written about valuable mineral discoveries which have come about by pure chance; and one need only look back upon the last half century to be convinced that these accidents have had a powerful effect upon the fate of nations. The finding of gold by Sutter brought a population to California which speedily discovered that the precious metal was not the only treasure obtainable from its soil; the peopling of the West unquestionably hastened the spread of civilisation across the whole continent, and in so doing very largely conduced to the prosperity and stability of the United States.

What would Australia be at the present day if the discoveries in the early fifties had not led to inrushes of eager gold-seekers? The same may be said of South Africa, and it is curious to speculate upon the far-reaching effects of the chance discovery of a diamond by an ignorant boy on the banks of the Vaal river and its recognition by a trader, only thirty-six years ago. If the riches of the Kimberley treasure vaults had not attracted miners to South Africa, we might have continued to wait decade after decade before the mineral wealth of the Transvaal would have become known to its pastoral inhabitants, and before any thought would have arisen of connecting the Cape with Cairo by rail. In a word, the rapid growth of our empire and of other countries has unquestionably been due in many cases to chance discoveries of mineral.

If chance has done so much, it may be fairly assumed that properly directed efforts, aided by all the resources of science, can surely do more; and it therefore behoves the student to make himself acquainted with the signs of mineral deposits often seen at the surface and with methods of discovery practised by those pioneers of civilisation known as 'prospectors.'

The indications which guide the prospector are precisely those upon which the geological surveyor depends in making his maps,

viz., form of the ground, colour, nature of decomposed outcrop, ordinary springs, mineral springs, special plants and altered vegetation, burrows of animals, old workings, slag heaps, and old records.

If the mineral deposit is harder or softer than the surrounding rocks, it will affect the manner in which the surface is sculptured by atmospheric agencies. Hard rocks will be left projecting, soft ones will be cut into hollows, especially if they are impermeable. The outcrop of a hard bed will be denoted by a steep face or escarpment, and unyielding mineral veins will project above the surface in the form of large crags (fig. 24).

In most parts of our country these outcrops have been worked away and are no longer apparent; but lode-quartz blanched by weathering may often be seen standing up several feet above the surface on the Welsh hills, and the run of some lodes may be traced for a long distance by a succession of these outcrops. Fig. 25 represents a huge outcrop of massive hæmatite in Brazil, known as the Pico d'Itabira do Campo. The hæmatite is exceedingly hard and has resisted erosion better than the enclosing rocks.

Deposits of soft substances like clay, or veins composed of yielding minerals, offer less resistance to rain, flood and frost, are more deeply cut into than the surrounding rocks, and have their presence indicated by depressions. The searchers for china clay in Cornwall are guided by signs of this nature.

Colour is an important factor in the discovery of mineral deposits. Sometimes the valuable mineral has a distinct hue. A bed of coal may be marked by blackened earth at the surface, copper minerals give rise to green, blue and red stains, which catch the attention very quickly. The common ores of iron are red, brown, or yellow or black; manganese ores are often black; lead ore furnishes a green, a yellow, or a white coating; cobalt a pink one, whilst cinnabar is the natural vermilion. Coloured minerals are often used as pigments by savages, and in this way may be brought to the notice of explorers.

A mineral deposit near the surface is frequently so altered by atmospheric agencies that it bears but little resemblance to the undecomposed bed or vein which will eventually be met with at a greater depth. A bed of hard shale will crop out at the surface as a soft clay; but the most common cases of change are furnished by the conversion of sulphides into oxides or oxidised compounds, and the removal of some of the material in the form of a soluble sulphate. Thus iron pyrites, which is such a frequent constituent of mineral veins, is converted

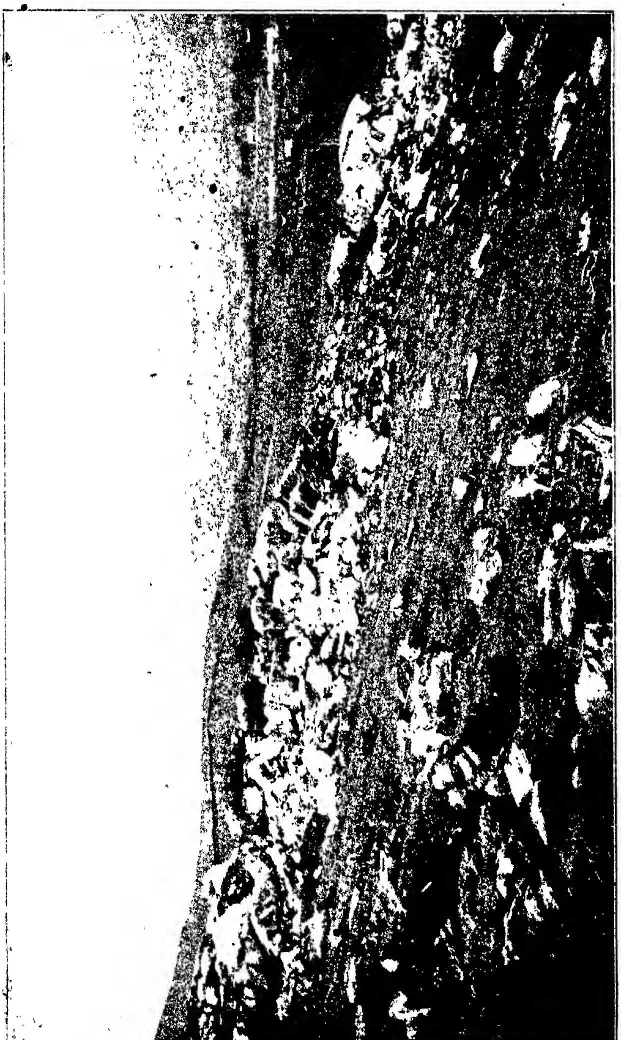


FIG. 24.—Projecting outcrop of Vigre Lode, near Dolgelly, North Wales.
From a photograph by Mr G. J. Williams, H. M. Inspector of Mines.

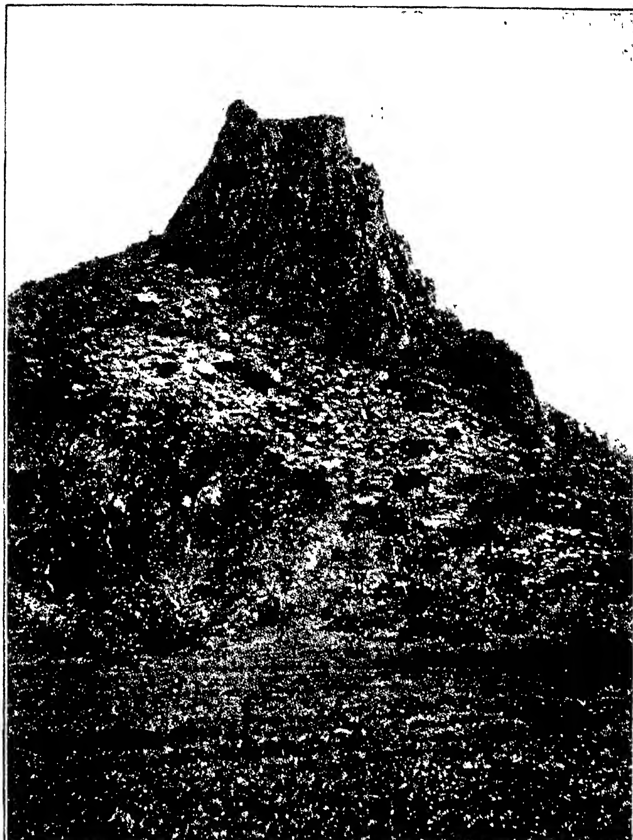


Fig. 25.—Pico d'Itabira do Campo, Minas Geraes, Brazil.*

The main body of ore is of massive hæmatite, the slopes being covered with rubble and some conglomerate ore. Between the crosses is about 50 metres.

* H. K. Scott, "The Iron Ores of Brazil," *Journal of Iron and Steel Institute*, vol. lxi., 1902, p. 240.

into hydrated oxide of iron, and a lode, originally consisting of iron pyrites and quartz, becomes a honeycombed brown and yellow rock, the removal of the iron pyrites in the form of a soluble sulphate leaving cavities which are only partly filled up by oxide. The ferruginous solutions will stain and discolour the adjacent rock as they flow away.

The ferruginous outcrop of mineral veins has been noticed in all mining countries. In Cornwall it is called *gozzan*, and this term has been carried by the ubiquitous Cornish miner to other English-speaking countries.

The nature of a gozzan varies according to the composition of the vein from which it is derived. If the vein originally consisted very largely of iron pyrites, the gozzan will be mainly ochre and brown iron ore, often in botryoidal and stalactitic forms. If quartz was present also, a cellular, cindery, cavernous, ferruginous rock is the result of the atmospheric weathering. The former presence of copper sulphides will be denoted by the oxides, carbonates, phosphates and arseniates of the metal, and the same holds good with lead; calamine points to the presence of blende.

The depth to which the oxidising and leaching action proceeds is occasionally only a few inches, but often several hundred feet. Sometimes there is a sharp line of demarcation, sometimes a gradual passage, between the gozzan and the undecomposed part of the vein.

Impervious beds, such as clay and shale, will bar the passage of rain water as it percolates down from pervious beds above, and so cause the issue of springs. A line of these may mark the outcrop of a bed of clay on a hillside.

Mineral veins are often channels for underground water, and may give signs of their existence, in an undrained country, by discharges at the surface.

If the water of a spring contains marked quantities of salt or of other minerals, it may indicate the presence of a workable deposit.

Both plants and animals may be of service to the prospector. As different plants require different nourishment, it is only natural to suppose that a change of soil causes a change in the vegetation.

Clays will retain water and naturally favour the growth of rushes and other moisture-loving plants.

The effect of salt in the rocks is especially marked, for there are many plants which either flourish best when getting salt or cannot exist without it. There are also special plants which are regarded by prospectors as indications of phosphate of lime and of the ores of copper, lead and zinc.

Though not indicated by any special plant, the presence of a

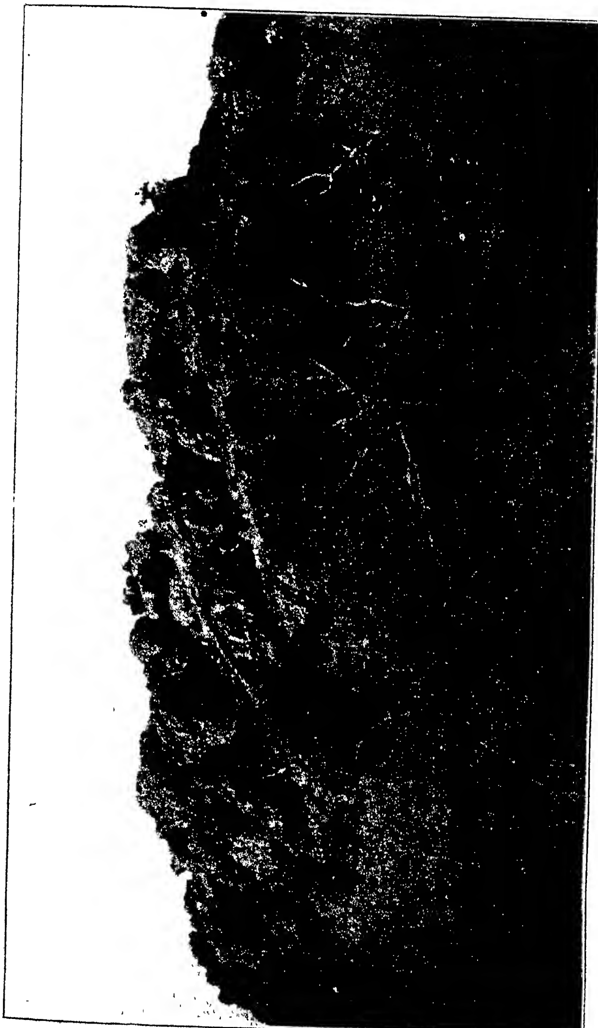


Fig. 26.—Huge outcrop of gozzan containing copper ores, at Mount Constantine, Cloncurry, Queensland.

mineral deposit may sometimes be suspected from an alteration in the appearance of the trees or grass along its course, according as the deposit in question exerts a favourable or unfavourable action on the soil. Many veins contain large quantities of iron pyrites, which produces plant poisoning sulphates as it decomposes It is only natural, therefore, to suppose that grass would grow less luxuriantly upon a wide pyritous vein than upon adjacent slate, and that a decided streak of altered colour and growth would be visible in the turf.

Any burrowing animal may bring up small fragments of a deposit hidden beneath the soil which otherwise would remain unnoticed. Green sand thrown up by a wombat led to the discovery of copper ore in South Australia; yellow earth in the burrow of a 'meerkat' (*ichneumon*) was the indication which guided a prospector to a diamond 'pipe' near Kimberley. Ants, gophers, moles, etc., have all been the means of furnishing signs of mineral deposits.

Traces of old workings, such as pits, gashes in the hillsides, and rubbish heaps, often tell useful tales (fig. 27). When the workings were shallow, the miner put down shafts in close proximity, and the line of a series of shafts and rubbish heaps will give a fairly correct idea of the strike of a lode. The rubbish heaps will show what was the ore worked, and with what it was associated. It often happens that mining refuse, thrown away as worthless in the days when dressing appliances were crude and rough, will pay for being worked over again. Even old ruins may be useful in pointing indirectly to mines. People do not settle in a country without a reason, and mining is sometimes their object. Fig. 28 illustrates a case in point.

Heaps of slag show that smelting operations have been carried on, and as carriage was difficult and expensive in old days, it may usually be assumed that there are ancient workings in the vicinity.

Old mine plans, reports and deeds should be consulted when available; and information should be sought from official geological surveys and mining records when they exist, as they do in this country. In Australia special maps are prepared by the Government for the use of prospectors.

A knowledge of geology may be of the utmost value in directing the searcher to localities where he has a reasonable prospect of success, or in teaching him where his efforts are sure to be fruitless.

If a given geological horizon in a neighbouring district or country has yielded some valuable bed of mineral, scientific knowledge will assist the would-be discoverer in ferreting out the

same horizon at home, or it may enable him to say at once that money spent in prospecting would inevitably be wasted.

FIG. 27.—Ancient workings for gold at Debach, Egypt.*

The discovery of the Coal Measures in Kent under a thick cover of Secondary rocks is the result of brilliant geological reasoning.

* Alford, "Gold Mining in Egypt," *Proc. Inst. M. M.*, vol. x., 1901 2, p. 2.

We now come to the actual processes of search. The commonest is known as 'shoading,' and it may be supplemented by 'trench-

FIG. 28.—Ruins of an ancient mining town in Egypt.*

ing.' 'Probing' and 'hushing' are valuable in certain cases, and finally the dipping needle is regularly used in searching for deposits of magnetic iron ore.

* Alford, *op. cit.*

The presence of a mineral deposit may be inferred not only from a conspicuous outcrop, standing out prominently above the ground, but also from fragments which have become detached in the process of weathering, and which now lie about on the surface or have been washed down the hillsides into the beds of brooks. Such loose fragments of veinstuff are known in Cornwall as 'shoadstones,' and the process of tracking the parent lode by their means is called 'shoading.' The prospector, armed with pick, shovel and pan, pursues his search more especially in places where he can obtain natural sections of the strata, such as the beds of brooks, and he carefully examines the stones which they roll along when in flood. From time to time he digs up samples of the gravel and washes it in his pan to see whether he can find traces of gold or other heavy metallic minerals. Pieces of the veinstuff in the brook, or particles of metal or ore washed up in the pan, tell of a deposit higher up, and the search is continued until from more frequent or more marked indications the prospector feels that the goal cannot be far off. Finally, he may be rewarded for his toil by the sight of a seam or lode laid bare by the brook, or by coming across a prominent outcrop on the hillside. By digging trenches at right angles to the presumed strike of the deposit, he is able to trace its course even when it is hidden under the soil.

Hushing consists in causing a stream of water to rush down the side of a hill and cut a ditch through the soil, so as to lay bare the outcrops of mineral deposits if any exist.

In some special cases when the mineral lies very near the surface, and is either harder or softer than the surrounding rock or has a peculiar colour, the searcher makes use of a sharp steel rod or a pointed stick, which he thrusts into the ground.

Kauri gum and the well-known French burr-stones, which lie in sand and soft clay at a depth of 10 to 18 ft., are found by this prodding or probing process, and the presence of tin-bearing gravel in the Malay Peninsula is detected in a like manner.

In the special case of magnetic iron the prospector employs a dipping needle. This consists of a magnetic needle delicately suspended so that it can move with great freedom; the prospector walks over the country and from time to time observes the needle. If one end dips down he knows that a deposit of ore is near. By making a number of observations he can trace out the shape of the deposit.

From the above remarks it will be seen that the miner is greatly aided in his search by a variety of direct and indirect indications; but in a new and unsettled country the physical difficulties are often so great, that strength of body and capability of supporting

fatigue and hardships become some of the most important qualifications of the prospector. He should have a general knowledge of geology, and understand mineralogy sufficiently to recognise all the common and valuable minerals and their ordinary associates, and to confirm his opinion by simple tests. The pick, shovel, and pan should be handled with ease, as well as the rifle and the gun. Keen and good eyesight is a *sine qua non*; a myopic prospector would fail to recognise natural features, and a colour blind person would not be struck by important differences of tint; finally, a sanguine temperament is desirable, for disappointments must be frequent. Under these circumstances it is not surprising that some persons compare the searcher for minerals to the maker of poems, and say: *prospector nascitur non fit*; but given the requisite physical and mental qualifications, it must be admitted that scientific training will greatly aid the prospector in his calling.

CHAPTER III.

BORING.

The principal purposes for which the miner employs boring are as follows:—

(*a*) To ascertain the nature of a mineral deposit, its depth from surface, thickness, dip and strike.

(*b*) To obtain liquid minerals, such as brine or petroleum.

(*c*) To obtain gaseous minerals, such as natural inflammable gas, carbonic acid gas, vapours containing boric acid.

(*d*) To drain off gas from rocks, and water or gas from mine workings.

(*e*) To make passages for conveying power into underground workings by steam, water, wire ropes, or electricity.

(*f*) To introduce pipes carrying a freezing solution, for the Poetsch or congelation process.

(*g*) To excavate mine shafts.

There are three principal methods of boring, viz.:—

1. By rotation.
2. By percussion, with rods.
3. By percussion, with ropes.

(1) Boring by Rotation.

Soft rocks, such as clay, soft shale, sandy clay, and sand can be bored by an open auger like the common carpenter's tool. As the hole is deepened, the handle has to be lengthened after the fashion of the well known chimney-sweep's brush. But the rocks most commonly explored by the miner are too hard for such augers, and are attacked by tools in the form of hollow cylinders armed with diamonds or with steel teeth.

The working part of the diamond drill consists of the so called 'crown,' which is a short hollow cylinder of cast steel, at one end of which a number of black diamonds are fastened in small cavities. The crown is screwed on to wrought-iron pipes, which are made to rotate, with the result that an annular groove is cut

at the bottom of the hole, leaving a core. The sand and mud formed by the abrasive action of the diamonds are carried up by

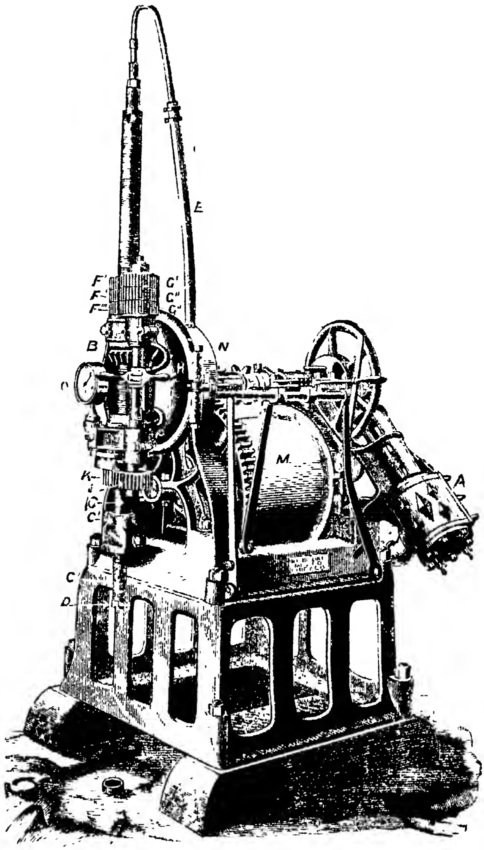


FIG. 29.

the stream of water pumped down the rods, which ascends through the annular space around them.

The 'Dauntless' (fig. 29) is one of the diamond drills made

by the Bullock Manufacturing Company of Chicago, for boring prospecting holes, and is capable of drilling a 2-in. hole to a depth of more than 2000 ft. and furnishing cores $1\frac{7}{16}$ in. in diameter. Cores showing visible gold have been brought up from a hole 2500 ft. deep, bored by one of these drills near Johannesburg.

The machine is constructed as follows: A is one of a pair of cylinders, driven by steam or compressed air, which work the bevel wheel B by gearing. The feed screw C C can slide readily up and down through B; but as B carries a feather lying in a slot in C, the latter is driven round when the former rotates. D is the crown set with diamonds, screwed on to the first piece of boring tube C″, attached to C by the chuck C′. The hose E, coming from a special pump, brings in a continuous supply of water which passes down C and comes out through D; F′, F″, F‴, and G′, G″, G‴, constitute the differential feed-gear for causing the feed-screw C, and consequently the bit D, to descend as the hole is deepened.

F′, F″, and F‴ are connected with B so that they revolve when it does; G′, G″, and G‴ are loose on the counter-shaft, but any one of them can be made fast to it by operating the clutch H. K is a toothed wheel attached solidly to the bottom of a feed nut through which C passes; when K rotates it causes C to ascend or descend L is a wheel equal in size to K, which it drives when the shaft is rotated by G′, G″, or G‴.

If F′ and G′ had the same number of teeth each, one revolution of B would make one revolution of G′, one revolution of L, and one revolution of K; consequently the feed-nut attached to K would be revolving at the same rate as C, and C would not descend. In reality G′, G″, and G‴ have a slightly smaller number of teeth than F′, F″, and F‴; therefore one revolution of F′ causes slightly more than one revolution of G′. K moves rather faster than C, and C descends slowly. As arranged in this particular case, the gear F′ G′ causes C to descend one inch for every 300 revolutions, the gear F″ G″ gives a feed of one inch for every 450 revolutions, and F‴ G‴ a similar feed for 750 revolutions. The driller is thus enabled to regulate his feed to the hardness of the rock bored. In practice these three speeds of advance have been found sufficient.

M is a drum which is used for hoisting the rod out of the hole; N is a hinge upon which the whole of the boring head can be turned, so as to leave the mouth of the hole perfectly free while raising or lowering rods. O is the thrust register, upon which is indicated by a dial the resistance exerted by the rock against the bit. This is an addition of great importance, for by watching the

indicator the driller can detect changes in the hardness of the strata passed through, and can measure the exact thickness of the hard and soft beds before he has seen either the cuttings or the cores. The thrust register prevents the possibility of drilling through a bed of coal or other mineral without its being noticed, as has happened when the seam was so soft that it failed to furnish a core. The rod is lengthened as the drilling proceeds by screwing on piece after piece between C′ and the topmost rod projecting above the hole.

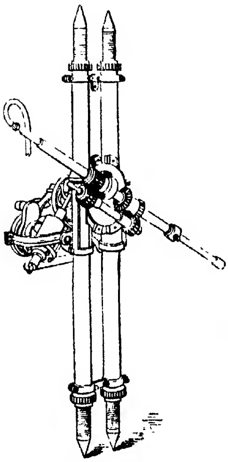


FIG. 30.—Small prospecting Diamond Drill for use underground, driven by compressed air.

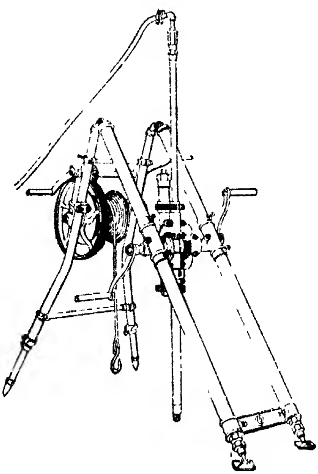


FIG. 31.—Sullivan hand-power Prospecting Drill.*

After drilling has gone on for a while, the rods are drawn up, and the crown is replaced by an extractor which will wrench off the core and hold it fast till it is brought to the surface.

Small diamond drills, which will bore in any direction, and which are driven by hand, compressed air, or electricity, are largely used both above and below ground for prospecting.

* Lane, "Diamond Drilling Machines," *Mines and Minerals*, vol. xx., 1900, p. 244.

Exploration by these little machines is very decidedly cheaper than by driving or sinking by hand in hard rocks, and fully ten times as quick. On the other hand, the ground is not opened out as it would be by a shaft or drift, and the sample furnished is but small.

The Calyx drill works in the same manner as the diamond drill, save that the annular groove is cut by steel teeth instead of diamonds.

In fig. 32, A is the toothed steel crown, shown on a larger scale below, it is screwed into the core-barrel B, to the upper end of which is attached the reducing plug C. This receives the lowest of the hollow lengthening rods. D is a long tube above the core-barrel which catches the coarser particles of detritus and holds them until the tool is drawn up to the surface. The arrows show the course of the flushing water, which is pumped down the hollow rods and ascends outside the core-barrel. On reaching the top of the sediment tube, or 'calyx,' the velocity of the current is at once greatly diminished, owing to the increase in size of the annular space, and the heavier particles fall to the bottom as shown. When the core has been cut out so deeply that it nearly fills the core-barrel, some small pebbles are dropped down the hollow boring rods. They fall between the core and the inside of the core-barrel, wedging themselves in tightly; the core is thus gripped so firmly that it breaks off when the rods are lifted, and is brought to the surface with the core-barrel.

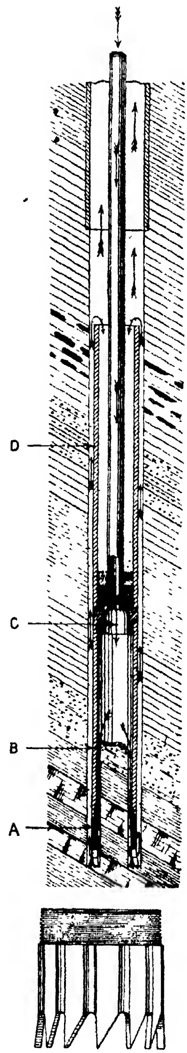


FIG. 32.—Davis Calyx Drill.

(2) Boring by Percussion with Rods.

The rods are made either of iron or wood.

An ordinary boring plant consists of

the cutting tool, the rods, a suitable frame-work or derrick for the purpose of conveniently raising and lowering them, and the necessary driving machinery; in addition, there must be clearing tools, and appliances for remedying accidents, lining the bore-holes, and obtaining samples of the rocks traversed.

The actual cutting tool is usually a chisel of some kind. For soft rocks the edge is straight; for hard rocks there are wings to guide the tool and keep the hole vertical, or even special guides above it.

The lengthening bars or rods are made of iron of square section. The usual mode of connection is a screw joint, care being taken to have all the bars alike, so that any two bars can be screwed together.

The height of the derrick, tower, or shears erected above the bore-hole should be some multiple of the length of the rods, so as to be able to detach or attach two or three lengths at a time, instead of having to make and unmake every joint. The rods have two shoulders at each extremity, so that the upper one can be used with the lifting hook when the lower is resting on a key. A cap may be screwed on to the topmost rod and used for raising the rods instead of employing a lifting hook.

The work of boring consists in raising the rods and allowing them to drop and let the chisel fall upon the bottom of the hole, each time that they are raised they are turned slightly in order that the successive blows of the chisel edge may strike different parts of the bottom of the hole. After the chopping action of the chisel has gone on for a time, the detritus must be removed by a clearing tool, and before this can be done the cutting tool must be taken off. The rods are drawn up and taken off length by length, and as soon as the hole is free the clearing tool is lowered, either by the rods in precisely the same way as the boring chisel, or by means of a rope and windlass. The clearing tool is usually a hollow cylinder with an ordinary clack valve or ball valve (*shell-pump* or *sludger*) (No. 7, fig. 34). It is worked up and down a little till it is filled, and it is then drawn up to the surface and emptied. The operation is repeated if necessary, and the boring is resumed with the rod. Where labour is cheap, bore-holes may be put down even to a depth of 200 ft. without any appliances beyond the rods, the chisel, the sludger, and some large spanners for making and unmaking the joints and holding up the rods. Dr Walter Saise, the Superintendent of the large mines of the East India Railway, has been most successful in boring for coal in this manner; but in Europe recourse is had to mechanical appliances long before such depths are reached.

For depths not exceeding 60 to 80 ft., Arrault, a well-known French engineer, employs the simple plant shown in fig. 33. The man at the windlass raises the rods by turning the handle, and the master borer detaches them and causes them to fall by simply

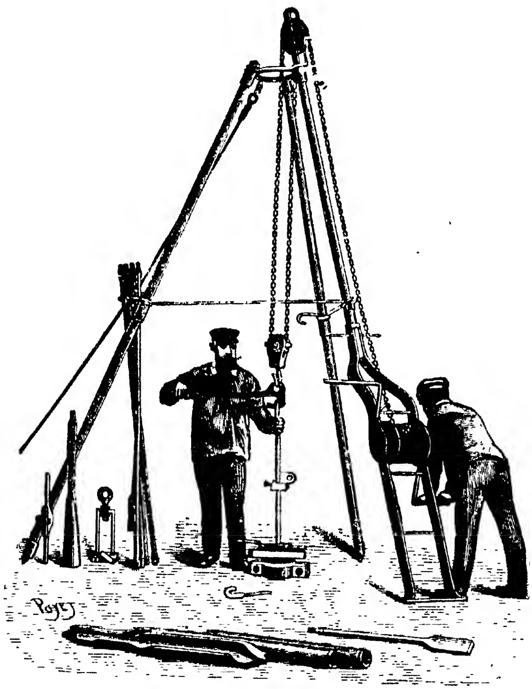


FIG. 33.—Arrault's small portable Boring Plant.

pressing down the end of the hook, which he holds in his right hand. The chain is lowered, the hook put in, the rods are raised by the winch, and then again allowed to fall, the master borer taking care to turn them a little each time.

Fig. 34 shows the principal tools supplied by Arrault for a small boring.

For greater depths a lever is usually employed, the rods being suspended at one end, while the other is moved up and down by hand or by machinery.

Two methods of boring with iron rods much employed of late years on the Continent are those of Fauck and Raky.

Fauck's method consists in giving the cutting tool a rapid but very short stroke, whilst at the same time the bottom of the hole

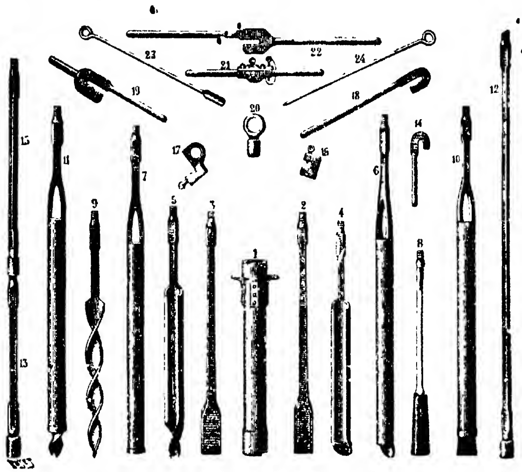


FIG. 34.—Tools for a small Boring Plant.

1, guide tube; 2, bit or chisel with wings; 3, straight bit or chisel; 4, ordinary open scoop or wimble; 5, scoop or wimble with auger; 6, closed scoop; 7, sludger with ball valve; 8, bell-screw or screw grab; 9, auger; 10, combination bit and sludger with ball valve; 11, combination auger and sludger with ball valve; 12, boring rod; 13, matching piece; 14, wrench for unscrewing rods; 15, matching or lengthening piece; 16, clamp; 17, clamp with eye; 18, wrench; 19, retaining or supporting key; 20, cap; 21, tiller; 22, double wrench; 23, scraper; 24, picker.

is constantly flushed by a current of water brought down through the hollow rods. No beam is used, but the chain or rope to which the rods and boring tool are suspended has an up-and-down motion imparted to it by the aid of an excentric. This arrangement enables the number of strokes per minute to be increased very considerably, even up to 250, whilst the length of the stroke is often as low as 3¼ in. (80 mm.).

The main wheel A carries the excentric B, the appliance which imparts motion to a chain or rope, attached by one end to the drum C upon which the reserve is coiled. The other part of the chain or rope passes over the guide pulley D, under the excentric B, over the two guide pulleys E and F, and hangs down to G. This end is attached to a swivel just above the first rod. When A revolves, the excentric alternately presses down the chain and lets it come up; the amount the tool is raised and lowered is evidently equal to twice the stroke of the excentric.

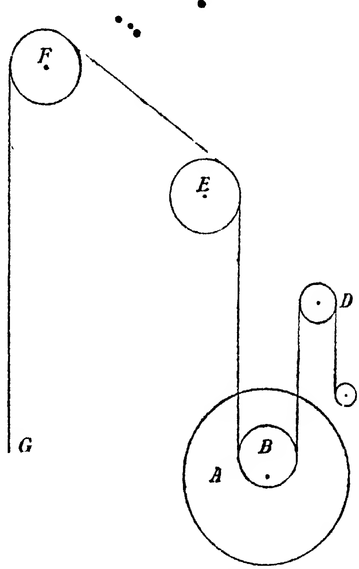


FIG. 35.—Diagram showing action of Fauck's Rapid Drill.

The boring tool itself is usually a chisel; when cores are required, it is replaced by a toothed hollow cylinder. By reversing the direction of the flushing current, Fauck is able to obtain cores continuously without stopping the work. They break off of themselves from the vibrations produced by boring, and are washed up the hollow rods and caught at the top.

The principal peculiarities of the Raky system of boring are as follows:—

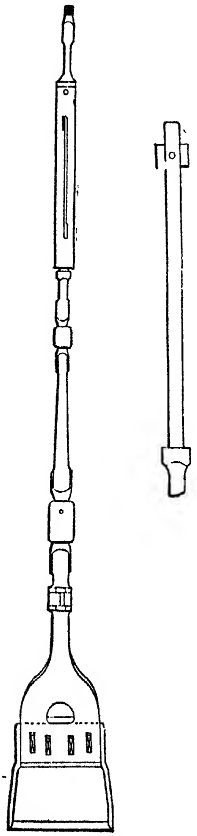
(*a*) Beam supported on a bearing carried by springs with the object of giving elasticity to the working parts.

(*b*) Stroke rapid and short; 80 to 120 blows per minute, of 3 or 4 in. each.

(*c*) Rods made of Mannesmann tubes.

(*d*) Water flushing.

Wooden Rods.—In some districts wooden rods are found more suitable than iron ones. They have been largely used in Canada,



FIGS. 36, 37.

The piece supporting the boring tool has two wings which rest upon shoulders at the top of a long slot in a cylinder attached to the lowest rod; by giving the rods a sharp turn to the left, the wings lose their support and the tool drops.

and hence the system of employing them is known as the Canadian method of boring.

Wooden rods are lighter and more easily manipulated than iron rods, besides which they are more easily repaired, a matter of much importance in districts far from foundries and engineering shops.

The rods are often made of two ash poles joined together by strapping plates of iron; at each end a forked iron coupling is riveted on, terminating by a conical male or female screw.

Free-falling Tools.—When a large or deep hole is being bored, the weight of the rods is so great that much vibration ensues when they are suddenly arrested by the chisel striking against the bottom. Various devices have been contrived for overcoming this difficulty, among which may be mentioned the free-fall tool shown in figs. 36 and 37.

Accidents.—Tools for dealing with accidents are numerous, and many of the contrivances used are very ingenious.

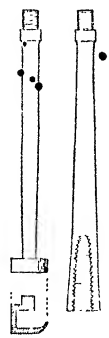
Among the accidents is a breakage of the rod. If the rods are not tightly jammed in, a claw called a crow's foot (fig. 38) is lowered and turned round till it catches a rod below one of the shoulders; it is then drawn up.

The tool shown in fig. 39 serves to cut a thread upon the end of a broken rod. The position of the broken end is first ascertained by taking an impression upon tallow or wax, and the cone is then lowered on to it; by turning it round, a thread is cut on the broken end, which gives hold enough to raise the

rods. Broken ropes can be caught and drawn up by tools resembling a corkscrew.

If the cutting chisel is broken, some kind of grasping nippers may be used to fish it up, and more recently a strong electro-magnet has been successfully employed for the purpose. A big broken chisel, weighing as much as 2 cwt., may even be gradually chopped up into pieces by continuing the boring process with a new tool. The small fragments are then extracted without difficulty.

Linings.—Where the strata are soft and would fall in, the hole has to be lined with a tube. Tubes are usually made of iron or steel.



FIGS. 38, 39.—Crow's Foot and Bell-screw.

FIG. 40.—Lining Tube for a Borehole.

Fig. 40 is a tube of riveted sheet iron with sockets fixed on, which enable the joints to be made by screwing. The tube may be made with screwed joints, so arranged that it is perfectly smooth outside and inside.

(3) Boring by Percussion with Rope.

The use of the rope for boring is of very ancient date in China, and the process has been brought to great perfection in America for the purpose of obtaining petroleum and natural gas.

The first operation consists in erecting the drilling rig, consisting of the derrick, steam-engine, band-wheel, walking-beam, bull-wheel and sand-pump reel.

The derrick (fig. 41) is a framework in the form of an acute truncated pyramid, 72 ft. high, 20 ft. by 20 ft. at the base, and about 3 ft. square at the top

By means of a belt, power is transmitted from an engine to a wooden pulley (*a*) called the band-wheel; this is provided with a crank (*b*), and through a pitman (*c*) it actuates one end of the walking beam (*d*), 26 feet long. A smaller pulley bolted on to the band-wheel enables the bull-wheel (*e*) to be driven by an endless rope, and, by means of a lever, a friction pulley (*f*) can be brought against the band-wheel so as to drive the sand reel.

In addition there are required :—

1. A set of drilling tools (h, i, j, k, l).
2. A sand pump (m), or a bailer.

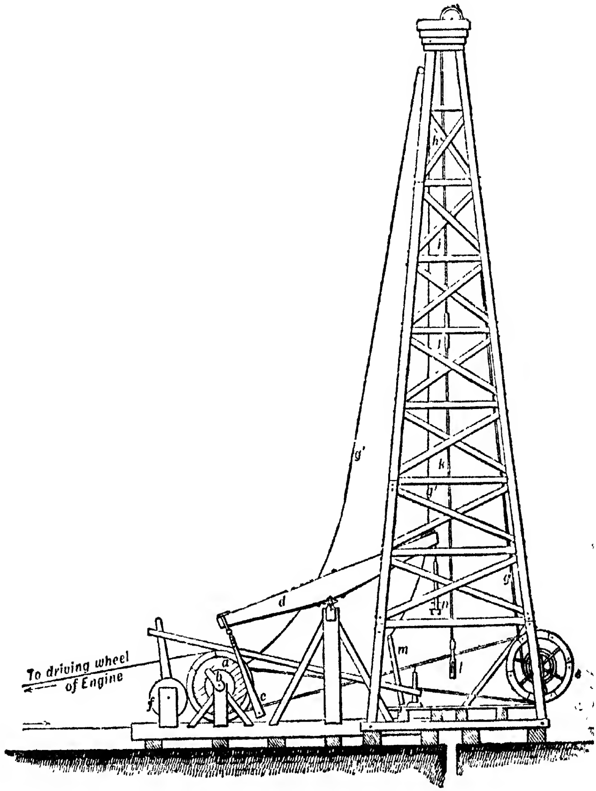
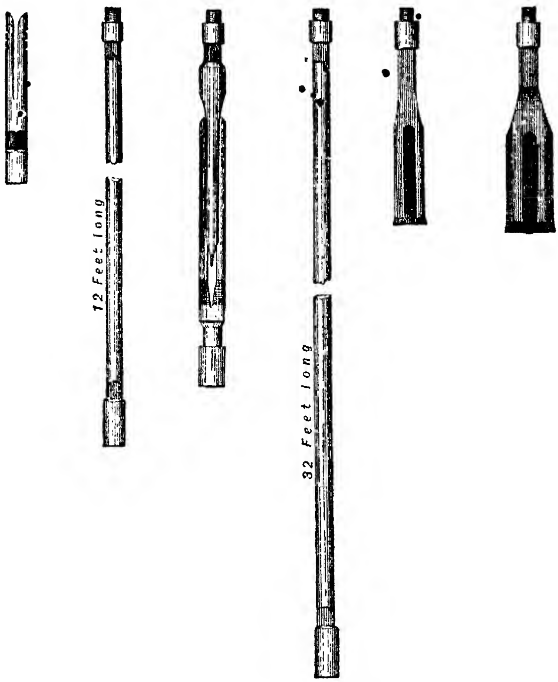


FIG. 41.—American Plant for boring with Rope.

3. A rope (g), 1 inch in diameter, for lifting the tools.
4. A rope (g'), 1 inch in diameter, for working the bailer or the sand pump.

The set of drilling tools is about 60 ft. in length, and consists of the following parts:—Rope socket, fig. 42 (and *h*, fig. 41); sinker bar, fig. 43 (and *i*, fig. 41); jars, fig. 44 (and *j*, fig 41);



FIGS. 42 to 47.—American Drilling Tools.

auger stem, fig. 45 (and *k*, fig. 41); bit, figs. 46 and 47 (and *l*, fig. 41).

The jars are like two links of a chain, and their object is to enable an upward blow to be struck if a bit sticks; the force of this upward blow is increased by the momentum of the sinker bar.

The rope-socket receives the end of the boring-cable, any part of which can be connected to the walking beam by a clamp arrangement attached to an adjustable link called a temper screw (fig. 48).

The bailer is a wrought-iron cylinder 18 or 20 ft. long, with a valve in the bottom, which opens as soon as its projecting stem touches the ground.

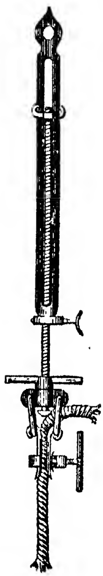


Fig. 48.—Temper Screw.

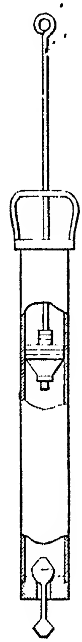


Fig. 49.—Sand Pump.

The sand pump (fig. 49) is an iron cylinder 5 ft. or more long, with a valve in the bottom and a piston. When it is lowered to the bottom of the hole the piston descends, and when the piston is raised, it sucks the mud and debris into the cylinder, and they are retained by the valve.

The proper cable is placed upon the bull-wheel shaft, one end brought over the crown pulley and attached to the socket, and to this, in succession, the sinker-bar, jars, auger stem, and bit. The temper screw (fig. 48, and *n*, in fig. 41) is clamped to the cable, and its eye hung on the hook at the end of the walking beam; the cable is now lowered, and the string of tools hangs from the walking beam. The engine is set in motion, and as the band-wheel revolves, the crank turns and causes the walking beam to move up and down, and the bit strikes a succession of blows at the bottom of the hole. As the hole deepens, the screw above the clamp is fed out, and when it can go no further the clamp is loosened, and shifted higher up after the screw has been run back.

The sand, gravel, and mud made by the chipping motion of the bit are removed by the sand pump lowered and raised by

the special rope on the sand-pump reel, driven by the friction pulley. The two operations, drilling and clearing out, are repeated until the hole has reached the required depth.

The American system presents very great advantages, especially where holes have to be numerous, and where it is not certain how long a well will retain its productiveness. On the other hand, in making preliminary explorations of the rocks of a new district, some of the other systems may fairly claim the superiority, because they furnish actual cores, showing the dip, which give a better idea of the strata than pounded fragments.

The Keystone drill, which is largely used for prospecting purposes, is a portable, self-contained rope-drilling plant, operated by a double walking beam carrying guide pulleys round which the boring rope passes from the winch on the carriage to the sheave on the top of the derrick.

The driving pipe, which also serves to line the hole, usually slightly precedes the drill, and drilling and driving go on alternately.

CHAPTER IV.

EXCAVATION.

Mining excavations may be made by hand or by machinery, and as the kinds of ground in which the work is carried on vary within the widest limits, from loose quicksands to the hardest rocks, the appliances required and the methods of attack employed are necessarily numerous.

I propose to divide the subject into three parts as follows:—

1. Excavation by manual labour.
2. Excavation by machinery driven by steam, water, compressed air, or electricity.
3. Certain special methods of excavation.

(1) Excavation by Manual Labour.

When excavations are made by hand, the principal appliances used are: crowbar, shovel, pick, wedge, and tools for boring holes and explosives.

The crowbar is an iron lever. It is used for prising off blocks of stone, and for shifting them after they have been detached. In some cases it is the only tool employed in getting the mineral.

Shovels vary a good deal in shape and make, according to the special purpose for which they are employed; for instance, the large broad blade used for shovelling coal would be greatly overcharged if filled with heavy lead ore.

The shovel consists of a plate or blade of iron or steel to which a wooden handle is attached by means of a socket or two long straps. It is used for excavating soft or loose ground, and for shifting material broken up by other tools.

Easy ground, such as hard clay, coal, shale, decomposed clay-slate and chalk, requires the use of the pick and the shovel; the pick breaks up the ground or cuts a preliminary groove in it, and the shovel serves to shift the broken material.

The pick is a tool of variable form, according to the material

operated on. Thus there are the navvy's pick, the poll-pick, with a point and a striking end (fig. 50), and numerous varieties of the double-pointed pick (fig. 51), the special tool of the collier, but also largely used in ore and stone mining. The

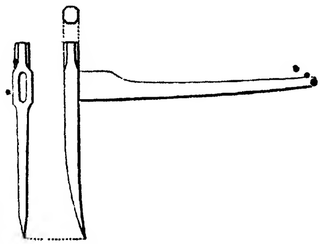


FIG. 50.—Poll Pick.

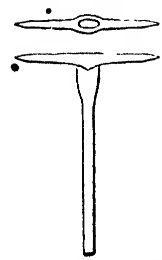


FIG. 51.—Double Pointed Pick.

blades of picks are made of iron with steel tips, or else entirely of steel. The tip may be a point or a chisel edge.

For convenience in taking the blunt tools to be sharpened, the blade is sometimes made so that it can easily and rapidly be

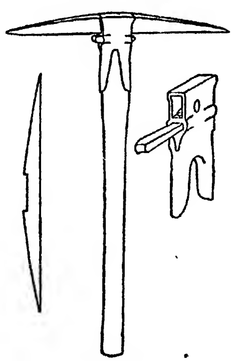


FIG. 52.—Acme Pick.

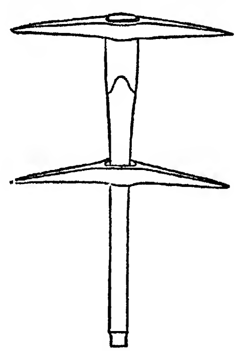


FIG. 53.—Universal Pick.

detached from the handle. The 'Acme' and the 'Universal' picks are of this class.

The Acme (fig. 52) is a pick used for 'holing,' or cutting a groove in soft rock, in which case it is advisable to have a tool as

narrow as possible, in order to avoid the unnecessary work which a broad eye would occasion. The blade is made with a notch at the top, and a wedge makes it fast to the head; blades vary from $1\frac{1}{2}$ to 3 lbs. in weight.

The Universal (fig. 53) has the large end of the shaft or handle fitted with a cast steel or malleable iron socket; the small end is put through the eye of the blade, which becomes firmly fixed, because the socket and eye are carefully made to gauge. By striking the small end of the handle on the ground the blade is loosened and removed. Blades of various shapes may be fixed upon the same handle, which is sometimes an advantage in remote districts.

When the ground, though hard, is nevertheless 'jointy,' *i.e.* traversed by many natural fissures, the wedge comes into play. The Cornish tool known as a *gad* is a pointed wedge (fig. 54).

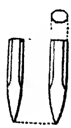


FIG. 54.- Cornish Gad.

The so-called 'pick and gad' work consists in breaking away the easy ground with the point of the pick, wedging off pieces with the gad, driven by a sledge or the poll of the pick, or prising them off with the pick.

In hard ground, such as slate of various kinds, hard grit and sandstone, limestone, the metamorphic schists, granite, and the contents of many mineral veins, excavation by boring and blasting is necessary, and even in softer rocks it is often economically advisable. The tools employed are the auger, jumper, drill or borer, hammer or sledge (*mallet*, Cornwall), scraper and charger, tamping bar or stemmer, and occasionally the pricker or needle and the claying bar.

Shell and screw augers, resembling the tools employed by the carpenter, are used in such rocks as coal, gypsum, chalk, shale and bituminous limestone.

For convenience of working, the auger is often supported on a frame and turned by a ratchet brace.

Fig. 55 represents the 'Conqueror' drill, which consists of a twist auger *a* inserted into a socket *b*, into which passes one of the square ends of the feed screw *c*; this works through a feed-nut *d*, supported by two pins, which lie in suitable recesses in an upright frame made fast against the roof by clamping the sliding part by the handle *e* and turning the foot-screw *f* by the handle *g*. The feed-screw is rotated by a ratchet brace *h* or *i*, and it carries with it the auger *a*. It works its way into the ground by the abrasive action of its cutting end, and is fed forward at the same time, because the screw *c* travels through the nut *d*. When the boring

has proceeded so far that the rear end of the feed-screw has come up to the standard, the auger is taken out and a longer one inserted. Instead of turning the feed-screw backwards, which would take time, it is reversed, for either end will fit into the socket *b*, and work is resumed without delay.

In these days of powerful explosives, wedging may seem a primitive method of excavating; but it is resorted to in some fiery collieries in order to escape the danger of igniting gas or coal dust by blasting.

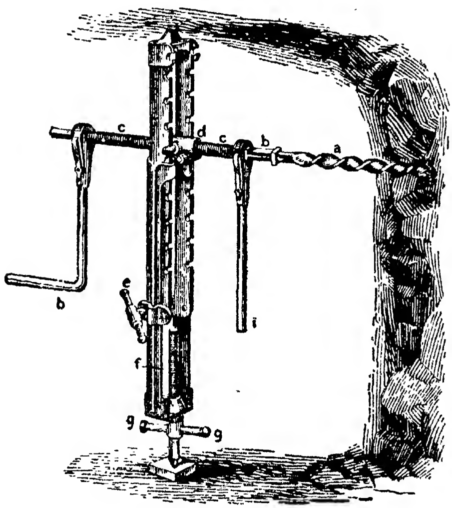


FIG. 55.—'Conqueror' Rotary Drill.

A compound wedge inserted into a borehole exerts a powerful splitting action when the central piece (*plug*) is driven in by a sledge hammer, especially if the rock is already severed on one side. François* of Liége has introduced an ingenious ramming device, which enables the miner easily to strike a far heavier blow than is possible with a sledge hammer (fig. 56). A is the floor of a coal seam B; C is shale, and D is sandstone roof; E F is a

* Collin, "Note sur les nouveaux procédés de coupage des voies,' *Revue Univ.*, vol. xxxviii., Liége, 1897, p. 268.

hole which has been bored and into which have been placed two 'feathers' (fig. 57). The tail end of the wedge G is formed by a long square rod on which slides a heavy ramming block H,

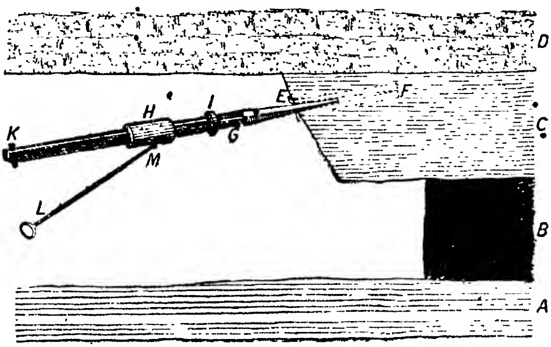


FIG. 56.—François wedge and ram, as employed for 'ripping' the roof after excavation of the coal, in order to make height for a roadway.

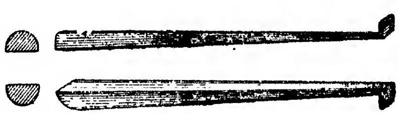


FIG. 57.

pushed by a bar L M. A very large number of these appliances are in actual use on the Continent.

Holes may be bored in tough clay or tough hæmatite by driving down a pointed steel bar. At some open workings for iron ore in Minnesota,* holes $1\frac{1}{4}$ in. in diameter and 20 ft. in depth are made in this manner; the borer is withdrawn by means of a double-claw gripping appliance, which seizes it firmly when pressure is applied by means of two levers (fig. 58).

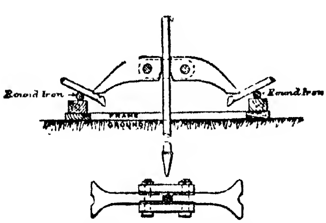


FIG. 58.—Gripping Appliance for withdrawing a Boring Bar.

* Head, "The Lake Superior Iron Ore Mines," *Proc. Inst. C.E.*, vol. cxxxvii., 1898-99, p. 72.

Another simple tool used for boring holes by percussive action is the jumper, a bar of iron tipped with steel, forged into a chisel-shaped edge. It is struck against the rock, and turned a little at each blow, and in this way chips out a cylindrical hole.

The jumper of the Cleveland district (fig. 59) has a swelling at one end, and is wielded so as to bore holes at any angle.

At the Festiniog slate mines (fig. 60) the jumper has a swelling in the middle, and both ends are sharpened; the short end serves for beginning a hole, the large one for completing it.

When the rocks are harder, and also in situations where a jumper cannot be wielded, the miner must have recourse to a steel chisel, borer or drill, which is struck by a hammer or sledge. For hand drilling the steel is usually $\frac{7}{8}$ to 1 in. in diameter, but $\frac{3}{4}$-in. or even $\frac{1}{2}$-in. steel is sometimes used. The shape of the cutting edge of the hand drills used at the Minera mine, North Wales, is shown in figs. 61 and 62, the angle of the edge being rather less than a right angle.

The hole is bored by striking the drill with a steel hammer or sledge, and turning it after each blow. Boring is said to be single-handed if the miner holds the drill in one hand and wields the hammer with the other; and it is called double-handed when one man strikes whilst the other turns. Sometimes there are two men to

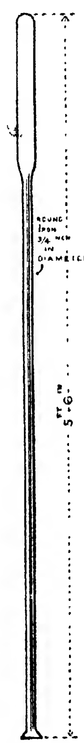


Fig. 59.—Cleveland Jumper.

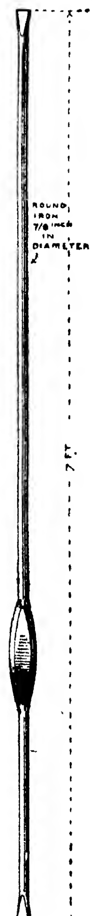
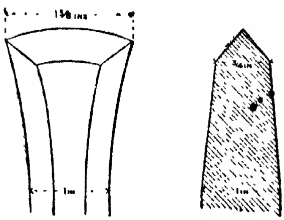


Fig. 60.—Festiniog Jumper.

strike, one after the other, whilst a third man turns the drill.

In starting a hole a short drill is chosen, and longer ones are taken as the hole is deepened; the smith is careful to make the cutting edges (*bits*) diminish slightly in width as the borers increase in length, because the hole gradually decreases in diameter as the tool wears.



FIGS. 61 and 62. Cutting Edge of a Steel Drill or Borer.

The hammers for single-handed boring vary in weight from 2 to 6 or 7 lbs. The hammers used by the Festiniog miners and quarrymen weigh from $5\frac{1}{2}$ to 7 lbs. (fig. 63). The handle is 10 to 12 in. long.

A good miner should be able to wield the hammer with either hand, because he may have to put in a hole close to either side of a level or stope; he should also be able to strike upwards, because occasions arise where a hole bored in this manner will be

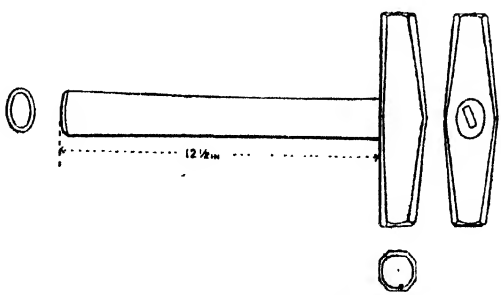


FIG. 63 —Miner's Hammer.

far more advantageous for removing rock than one bored downwards.

The double-handed boring hammer or sledge (*mallet*, Cornwall), weighs from 6 to 10 lbs. or more, and the handle is about 2 ft. long (fig. 64). If swung round by strong arms, it strikes a very powerful blow.

If the hole is directed downwards, the miner throws in a little water and bores the hole wet. A ring of rope or leather put round the drill prevents the water from splashing him. The water serves three purposes: it enables the tool to strike a better blow on the rock; it keeps it cool, and so makes it last longer; and finally it prevents dust, which would otherwise be breathed by the miner and tend to cause lung disease. The depth to which holes are bored varies with the rock, and with the nature of the excavation; but in driving levels in the ordinary way by hand, the depth is commonly from 18 in. to 3 ft.

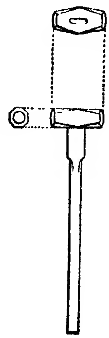


FIG. 64.—Sledge Hammer.

The scraper is a small disc fixed at the end of a metal rod, which is used for removing the dust from the bore-hole. The mud made in boring a wet hole (*sludge*) is drawn out with a 'swab-stick,' which is simply a wooden stick with the fibres at one end frayed into a kind of mop.

The tamping bar or stemmer is a rod of wood, copper, or bronze, and is used for ramming in clay, pounded slate, sand or the dust from the bore-hole, or other suitable material, upon the explosive, and so causing a resistance sufficient to make the gases generated by the blast rend the rock in the manner required.

The pricker, or needle, is a slender tapering rod of copper or bronze with a ring at the large end. It is used for maintaining a hole in the tamping, through which the charge can be fired by a squib, rush or straw.

The charging spoon is a hollow half cylinder of copper or zinc, at the end of a copper or wooden rod, which is used for introducing loose gunpowder into holes which are more or less horizontal.

Explosives are arranged by Order of Council under the Explosives Act, 1875, into six classes as follows:—

(1) Gunpowder; (2) nitrate mixtures; (3) nitro compounds; (4) chlorate mixtures; (5) fulminate; (6) ammunition.

This classification is consequently adopted in official documents and publications in the United Kingdom; but for the purposes of the miner alone, I prefer a somewhat different and somewhat simpler arrangement, especially as he requires nowadays to be acquainted with explosives, which, though not licensed here, are in use in other parts of the world. The following classification

is based upon the nature of the most important ingredient, and the six sub-divisions are as follows: (1) Nitrate of potassium; (2) nitrocellulose; (3) nitroglycerine; (4) nitrate of ammonium; (5) chlorate of potassium; (6) fulminate of mercury.

The first class contains ordinary gunpowder, Bull-dog gunpowder, and several other explosives in which nitrate of potassium is the predominant ingredient.

The formula commonly given for gunpowder is: 75 parts of saltpetre, 15 of carbon, and 10 of sulphur; but the powder used for blasting in mines generally contains less saltpetre than that which is employed for sporting purposes.

Mining powder is usually coarse-grained and highly glazed. It is used either loose, or in cartridges made by the men on the spot, or in cartridges supplied to them. Gunpowder compressed into cylinders of diameters suitable for bore-holes, and provided with a central hole for the insertion of the fuse, has lately been brought forward with some success; but it has the great disadvantage, shared with all hard cartridges, of not fitting the bore-hole so closely as a pulverulent or plastic explosive.

Though gunpowder has lost much of its former importance, owing to the greater strength of many of its younger rivals, it is still largely employed for several reasons, viz., its relative cheapness, its slower action, which renders it more suitable for blasting in certain soft rocks and for producing rents without any violent shattering, and, lastly, its freedom from certain dangers which cling to some of the nitro-compounds.

In Bull-dog gunpowder there is an increase of the oxidiser and a decrease of the inflammable constituents. Its average composition, exclusive of moisture, is as follows:—

Nitrate of potassium,	85·0
Sulphur,	1·5
Charcoal,	13·5
	100·0

Nitrocellulose, or guncotton, is little used alone as a mining explosive; it has the defect of giving off a large quantity of the very poisonous gas carbonic oxide when fired. This evil is corrected by adding an oxidiser such as nitrate of barium, or nitrate of potassium, and the explosive, tonite, obtained in this manner, is in favour with some engineers, as it never requires to be thawed, and is consequently exempt from one class of accidents. On the other hand, it is not plastic like dynamite.

The nitroglycerine class includes very many of the most powerful and important explosives employed in mining. Nitroglycerine itself is a light yellow oily liquid with a specific gravity of 1·6 which freezes at about 40° F. (4·4° C.). It explodes violently when struck, and its extreme sensitiveness to percussion has led to its use being prohibited in many countries. Nobel invented a method of employing it with comparative safety by causing it to be absorbed by an inert porous substance. This is the original dynamite, which consists of 75 per cent. of nitroglycerine and 25 per cent. of diatomaceous earth, commonly known by its German name Kieselguhr. Many other mixtures containing nitroglycerine are in the market, the other ingredients being chosen with a view either to increase the power of the product, or to cheapen its cost, or to mitigate its shattering action, or finally to render it less likely to ignite firedamp or coal-dust.

The following five explosives may be taken as examples, and their average composition is given in the table below.

Ingredients.	Blasting Gelatine.	Gelignite.	Carbonite.	Ardeer Powder.	Wetter-dynamite.
Nitroglycerine .	94	60	26	32·5	50·5
Kieselguhr . .	...	.	. .	12·5	16·8
Nitrate of potassium	.	28·5	33*	5·0	
Nitro-cotton . .	6	4	...	...	...
Woodmeal . . .	...	7·5	41	...	...
Carbon.	...	...	...	1·0	...
Sulphate of magnesium	...	...	...	49·0	32·7
	100	100·0	100	100·0	100·0

Blasting gelatine claims an advantage over dynamite, as every part of it does useful work, guncotton being an active ingredient instead of being inert like the kieselguhr; it further has the advantage of not being affected by water. Gelignite, with a smaller proportion of nitroglycerine than dynamite, is cheaper but less strong. In carbonite the powerful disruptive action of the blasting oil is lessened by the addition of a large proportion of a mixture of nitrate of potassium and woodmeal, and the explosive

* The nitrate of potassium may be replaced in part or wholly by nitrate of barium.

thus becomes fitter for breaking down coal. Magnesium sulphate has been incorporated with dynamite in the last two explosives with the object of profiting by its large proportion of water of crystallisation; this is converted into steam when the explosive is fired, and so much heat is absorbed in this manner that the temperature of the evolved gases is considerably lowered.

Among the nitrate of ammonium explosives I may mention two which are in common use in this country, ammonite and roburite. The average composition of the former is 88 per cent. of nitrate of ammonium and 12 per cent. of dinitro-naphthalene, whilst the latter consists of 86 to 89 per cent. of nitrate, and 13 to 9 per cent. of dinitro-benzole, with or without 2 per cent. of chloro-naphthalene. The French explosives Grisounite and Grisoutine belong to this class.

In the fifth class we have Cheddite and 'rack a rock.' The former is a mixture of chlorate of potassium, castor oil, and a nitro compound, such as nitro napthalene or dinitro-toluene. The latter is chlorate of potassium soaked with 'dead oil,' a dark heavy oil consisting chiefly of hydrocarbons, and derived from coal tar, or with a mixture of equal volumes of dead oil and bisulphide of carbon, or with dinitro-benzole. The cartridges of compressed chlorate of potassium are dipped in the liquid when required for use; the two ingredients, when separate, are not explosive.

Firing Shots.—For firing the charge, either directly or by a fulminating cap, three kinds of appliances are in common use, viz.:—

(*a*) Straws, squibs, 'germans,' etc.; (*b*) safety fuse; (*c*) electric fuse.

The first named require that a hole shall have been left in the tamping by the use of the pricker or needle. A straw filled with fine gunpowder, and having a slow match attached to it, is inserted into the needle-hole. The slow combustion of the match gives the firer time to retreat to a place of safety before the gunpowder in the straw is ignited and fires the charge.

Safety fuse is a cord $\frac{3}{16}$ to $\frac{1}{4}$ inch in diameter, containing a core of gunpowder introduced during the progress of manufacture. The cord is tarred over so as to guard the powder against damp; and, if more protection is needed, the covering is increased in thickness and a layer of varnish is interposed. For wet ground the outer part of the fuse is formed by one or two spiral coils of tape or by guttapercha. For blasting under water the coat of guttapercha is often strengthened against injury by tape or is doubled or trebled. Ordinary safety fuse burns at the rate of

about two or three feet per minute, so it is easy for the miner to secure ample time for retreat by taking a sufficient length. Besides, the interval for seeking shelter may be prolonged by attaching a piece of touch paper to the fuse, or by igniting it by a lighted candle-end placed underneath, which has to burn through the covering before the core takes fire.

Firing shots by electricity has important advantages. Unless there is gross carelessness, no premature ignition of the charge can take place, because the current is not applied until all persons have reached a place of safety; there is no chance of 'hang fires,' such as those which occur with ordinary safety fuse and have caused many accidents; and, thirdly, the electric igniter does not fire gas, whilst flames or sparks issuing from ordinary safety fuse have been known to cause an explosion.

Electric firing is effected in two ways:—(*a*) by glow fuses, or (*b*) by spark fuses. In the former, a gap in the circuit is bridged over by some material causing a resistance, either by a fine

Fig. 65.—Electric Low Tension Fuse.

platinum wire, or by a special composition containing graphite or particles of metal. The passage of a current of very low tension through the platinum wire, or of a medium tension through the special composition, causes heat enough to produce incandescence and ignition. In the latter (*b*) the gap is bridged over only by air and the passage of a high tension current produces a spark and ignition.

Fig. 65 shows the electric low tension or glow fuse of the Aetna Powder Company of Chicago.* A copper cap contains fulminate of mercury at one end, whilst at the other two copper wires, insulated by a covering of cotton, are held in place by sulphur. The bare ends of the two copper wires are connected by soldering on a small piece of fine platinum wire, and are surrounded by a priming of guncotton. When the electric current passes, the fine platinum wire becomes red hot and ignites the guncotton; this fires the fulminate, and in their turn the contents of the cartridge into which the cap has been inserted will be duly exploded.

* *Eng. Min. Jour.*, vol. lxviii., 1899, p. 100.

As an example of a medium tension fuse,* I will take that of Messrs Schmitt & Co. (figs. 66 and 67). *a a* are iron wires enveloped by thick paper *b*, which is tarred on the outside; *c*, paper cylinder; *d*, priming composition with particles which become incandescent; *e*, second case of paper or brass; *f*, ordinary detonator with fulminate of mercury.

In many cases it is desirable that certain shots should not go off until other adjacent shots have heaved their burden and so paved the way for the greatest efficiency of their followers. With the old method of firing, it is easy to arrange for this delay by giving a greater length of safety fuse; and, for the newer electrical firing, time fuses are likewise available.

Figs. 68 and 69,† represent a low tension time fuse, the gap between the two wires being bridged over by a thin platinum wire. *a* is either iron or copper wire covered with cotton and tarred; *f*, priming composition; *e*, fulminating mercury in a copper cap; *g* is a column of slow burning powder; *h* holes in the metallic cap *i* to allow the escape of the gases from the powder.

By suitably arranging the composition and length of the column *g*, the detonation of the fulminate *e* will not take place for two or three seconds after the ignition of *f*.

The glow fuses have an advantage over the spark fuses from the fact that they can be tested with a galvanometer before use to see whether the circuit is in order.

The current for glow fuses is most commonly produced nowadays by magneto-electric machines, and for spark fuses by frictional machines. The damp air of mines is a decided drawback to the latter.

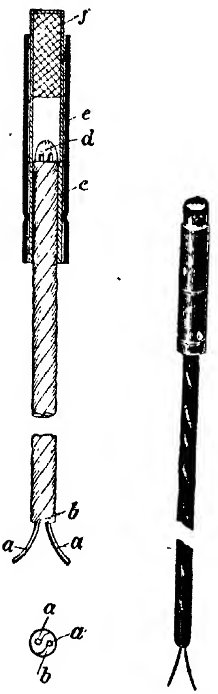
Driving and Sinking.—A level, heading, drift or drive is a more or less horizontal passage or tunnel, whilst a shaft is a vertical or steeply inclined pit.

In driving a level by hand labour in hard ground, the first thing a miner has to do is to 'take out a cut'—*i.e.* blast out a preliminary opening in the 'end' or 'forebreast.' The position of the first hole is determined by the joints or natural planes of division, which the miner studies carefully so as to obtain the greatest advantage from them.

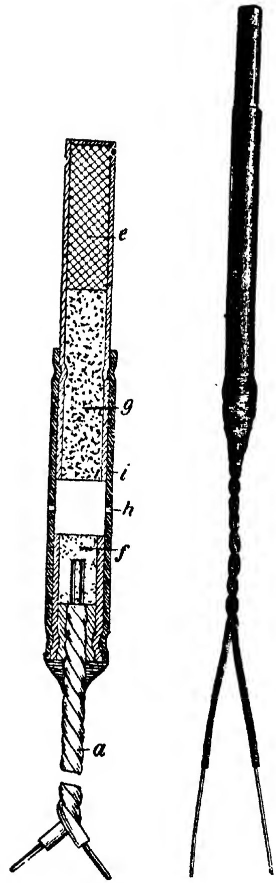
Thus fig. 70 shows a case in which, owing to joints, it was advisable to begin with hole No. 1, and then bore and blast 2, 3, and 4, one after the other. The miner, as a rule, does not plan the position of any hole until the previous one has done its work;

* Heise, "Fortschritte auf dem Gebiete der elektrischen Zündung von Sprengschussen," *Glückauf*, vol. xxxv., 1899, p. 437.

† Heise, *op. cit.*, p. 440.



Figs. 66 and 67.—Electric Medium Tension Glow Fuse.



Figs 68 and 69.—Electric Low Tension Time Fuse.

in fact, he regulates the position and depth of each hole according to the particular circumstances of the case.

Though a vein and its walls may be hard, there is occasionally a soft layer of clay (D D, DD, fig 71) along one wall (*dig*, Cornwall; *gouge*, U.S.). The miner works this away with the pick, and, after having excavated the groove as deep as possible, blasts down the lode by side holes, and so pushes the level forward.

In sinking a shaft a similar method of proceeding is adopted. A little pit (*sink*) is blasted out in the most convenient part, and the excavation is widened to the full size by a succession of blasts,

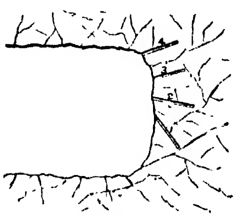


FIG. 70.—Arrangement of holes for driving a level by hand labour.

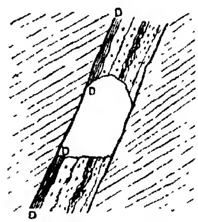


FIG 71.—Driving a level where there is a clay selvage.

each hole being planned according to circumstances. This series of operations is repeated, and the shaft is gradually deepened.

(2) Excavation by Machinery.

One of the greatest improvements in the art of mining during the last third of a century has been the introduction of machines for performing the most laborious work in place of doing it by hand.

In workings open to the sky, steam power may be conveniently generated on the spot, but for making underground excavations steam-driven machinery has so many drawbacks that it is scarcely ever used. The choice of excavating machinery in many mines depends therefore upon the best means of transmitting power from prime movers on the surface.

Power for excavating machinery is transmitted in mines and quarries in three different ways, viz., by air, water, or electricity.

The transmission of power by compressed air has the advantage that the exhaust escaping from the machines should benefit

the ventilation of the mine; there is, on the other hand, the drawback of very considerable loss of power.

In the case of water transmission, force pumps at the surface drive water through pipes to places underground where hydraulic engines are worked by its pressure, or water under pressure is drawn off in pipes from the rising main of the pumps. In both these cases any subsequent fall of the water, before it passes into the hydraulic engine, adds its effect to that produced by the engine above ground or by the column in the main.

Hydraulic power has the great convenience, therefore, that it is sometimes obtainable without any extra plant being required. The water, after having done its work, runs out naturally if the workings are above an adit, but has to be pumped up if they are below it. Hydraulic power has the disadvantage, when compared with pneumatic power, of not ventilating the workings.

Electricity generated by a dynamo, driven by any available power at the surface, is very easily conveyed by wires to an electric motor underground. One advantage of electrical transmission, compared with that by air or water, is that it is much easier to fix wires than pipes; wires occupy much less room, and do not suffer like pipes from movements of the rocks due to the workings. Like water, but unlike compressed air, electricity does not assist in ventilating the working place, and in fiery mines there may be danger from sparks. Compared with compressed air, an electrical plant is less expensive, and there is the advantage of a smaller loss of power in transmission.

Up to the present time transmission by compressed air has been far more largely used than either of the other two systems, but the advances in electrical practice render it likely that the newer method will soon overtake the older.

In the meanwhile it is necessary to describe some form of air compressor. A machine largely used is the Ingersoll-Sergeant compressor (fig. 72).*

It consists of a piston moving backwards and forwards in a cylinder. The piston is hollow, and on each face it has an annular valve B, T-shaped in section, lying in a circular slot concentric with the piston. A is a tail-pipe through which the air enters the piston; E and G are the outlet valves for the compressed air; F is the end of the pipe which conveys the compressed air to the reservoir. As shown in the figure, the piston is travelling forwards, the valve E is open, and the front valve B is closed; air entering A is passing into the hollow piston and thence through the rear valve B into the rear part of the cylinder. In order to

* *Mines and Minerals*, vol. xx., 1899, p. 42.

keep the ends and sides of the cylinder cold, it has an almost complete water-jacket, and a current entering at H or K passes around and leaves at I. J is an oil hole for lubrication.

Nowadays the work of compression is sometimes performed in two stages, and care is taken to cool the air from the low pressure cylinder before it is further compressed. Fig. 73 shows a section of the Sergeant vertical intercooler. It acts after the fashion of a surface condenser; the warm compressed air enters at the top, and passes down around a set of vertical pipes through which cold water is flowing continually; it then rises up and leaves at the side

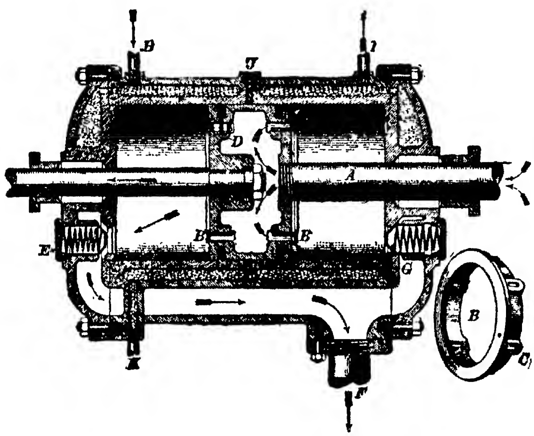


FIG. 72.—Ingersoll-Sergeant Air Compressor.

The machines used for excavating may be classified as follows:—

(*a*) Diggers and dredges.

(*b*) Drills for boring holes.

(*c*) Groove cutters.

(*d*) Tunnelling machines.

(*e*) Shaft-sinking machines.

(*a*) *Diggers and Dredges.*—These machines serve to excavate comparatively soft deposits near the surface, or to remove overburden, such as sand, gravel or stiff clay, or to dredge up the beds of rivers and lagoons. After a preliminary shattering by blasting, even hard rock may be removed by their aid.

The best known steam-diggers are Dunbar and Ruston's steam navvy, and the somewhat similar steam shovels of the Marion, Bucyrus and other companies in the United States. In each case a steam crane is made to bring a bucket, armed with teeth and a sharp cutting edge, against the side of an excavation, draw it up, swing it round and drop its contents into a railway waggon (fig. 74). Floated on a barge, the steam-shovel is used for scooping up gold-bearing sand and gravel from the beds of rivers.

Bucket dredges, similar to the machines used for improving harbours, are being used with much success for the purpose of excavating the gold-bearing alluvium of river beds or river-flats, and especially in

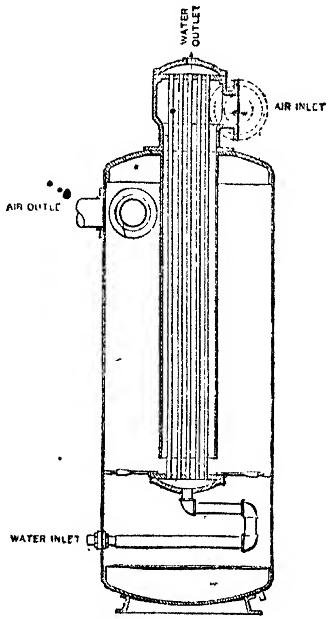


FIG. 73.—'Sergeant' Vertical Intercooler.

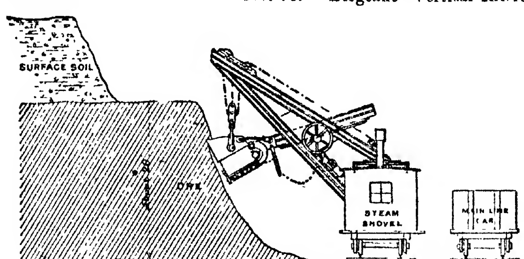


FIG. 74.—Steam Shovel digging iron ore, Mesabi district, Minn., U.S.A.*

* Head, "The Lake Superior Iron-ore Mines, and their Influence upon the Production of Iron and Steel," *Proc. Inst. C.E.*, vol. cxxxvii., 1899, p. 72.

New Zealand. The action of machines of this description will be understood at once from the figure. An endless chain of buckets, supported by a frame or 'ladder,' is made to scrape up the bottom. As a rule the buckets are worked by a steam engine on a barge, but fig. 75 * represents a dredge which is worked by an electric motor driven by power transmitted from a distance of four miles. The cylindrical screen serves to separate large stones before the gravel and sand are passed into the gold-saving appliances. An important feature of the dredge is the tailings elevator, which lifts up the big stones and gravel after the extraction of the gold and deposits them on the side. This particular dredge has buckets of 6 cub. ft. capacity, and will excavate 145 cub. yards per hour from a depth which may reach 50 ft.

The dredge shown in fig. 76 † was built by the Bucyrus Company, of Milwaukee, Wis., and is supplied with a Robins conveyor (see Chapter VII.) for stacking the tailings.

The grab dredge, sometimes known as the clam-shell dredge, is a semi-cylindrical or a hemispherical vessel, which is so contrived as to open when lowered, fill itself on touching the earth, and close as soon as it is raised. The raising and lowering are done by a crane. The Priestman grab dredger (fig. 77) is one of the best known; it has been used for excavating the auriferous gravel in the beds of rivers, and it likewise serves as a digging machine on land, and even for sinking shafts.

A third type of dredge may be described briefly as a centrifugal pump arranged to draw up sand and gravel with water. It is placed on a barge, and the suction pipe can be lowered, raised, or moved from one side to the other, so as to attack any part of the sea or river bottom. Machines of this description have been employed for excavating gold-bearing sand and phosphate of lime gravel.

(*b*) *Rock Drills.*—We now come to the machines which take the place of hand labour in boring holes for blasting or for wedging. Like the hand tools, machine drills may have a rotary or a percussive action.

A motor driven by compressed air or electricity is often attached to a twist drill similar to the hand tool already described on p. 59. Fig. 78 shows the Jeffrey drill driven electrically.

For working the Cleveland ironstone, a more powerful machine

* Hayes, *Report of the Department of Mines on the Goldfields of New Zealand for the Year* 1900. New Zealand, 1901.

† *Mines and Minerals*, vol. xxiii., 1902, p. 370.

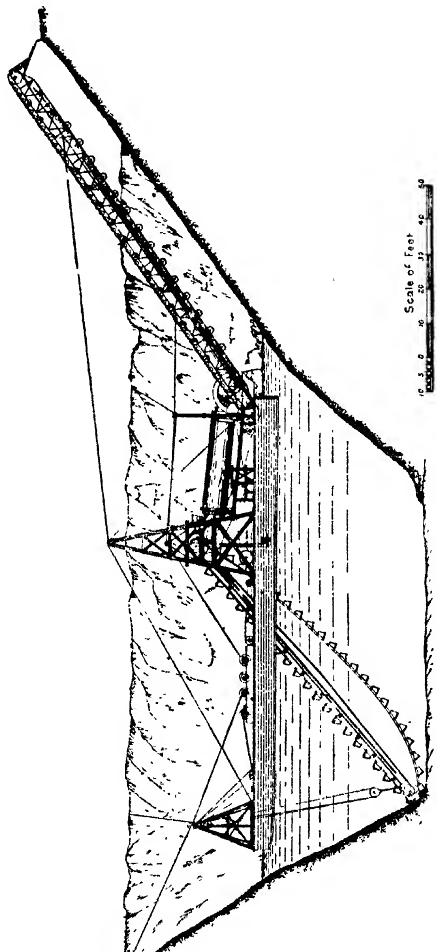


FIG. 75.—Earnscleugh No. 3 Dredge, New Zealand.

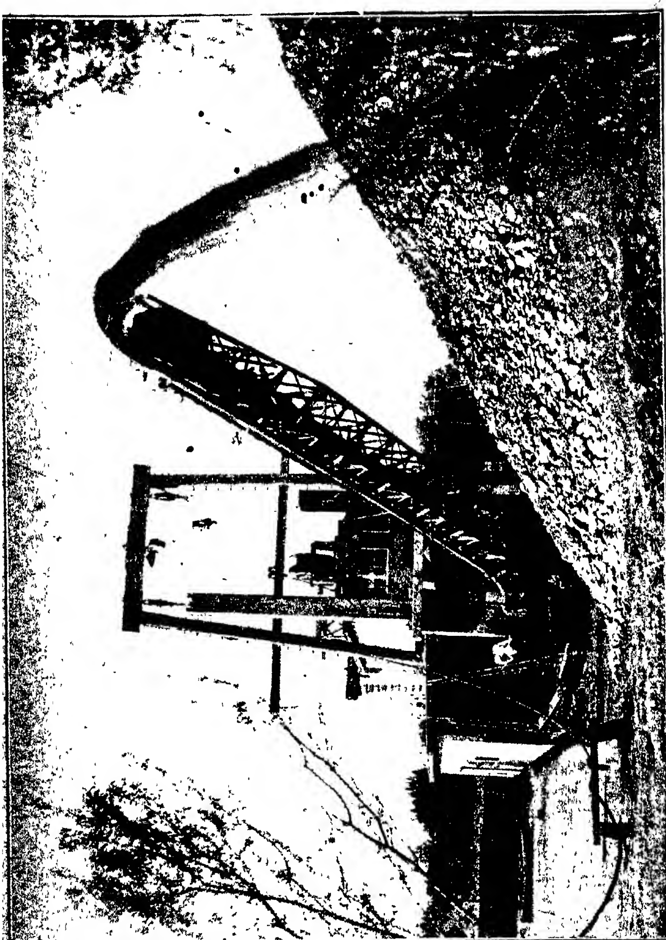


FIG. 76.—Bucyrus Co.'s Dredge with Robins conveyer for stacking tailings, excavating gold-bearing gravel at Oroville, Cal., U.S.A.

is employed. Fig. 79* shows one of these drills. A is the electric motor; B, hollow arm with a shaft inside driven by A, and working the bevel wheel C by suitable gearing; D, twist drill; E, socket for the drill; F, universal joint connecting the feed screw G to the drill socket; H, feed nut. The weight of the electric motor counterbalances that of the drill and gearing.

The Brandt hydraulic boring machine,† used with great success at the Simplon Tunnel, is a hollow rotary drill, through which a continuous stream of water is forced in order to wash out the debris.

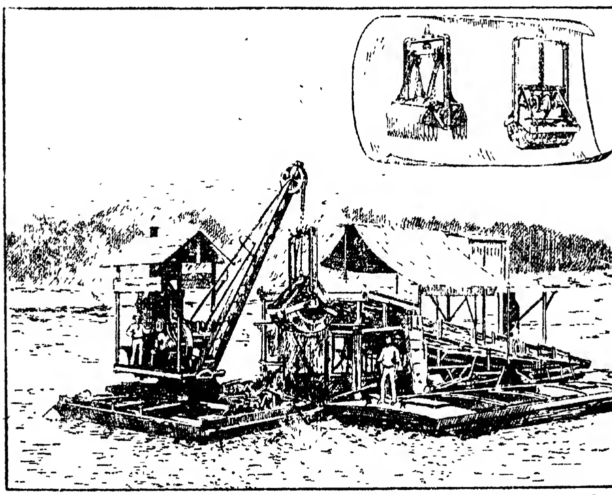


FIG. 77.—Priestman Grab Dredger, Nechi river, U.S. Colombia.

Two small single-acting water-pressure engines (figs. 80 and 81) drive a small shaft with a worm gearing into a worm-wheel Q; this is mounted upon the shell, R, of a hollow ram. S is a differential piston attached to the envelope or casing holding the

* Steavenson, "On the System of working Iron Stone at Lumpsey Mines by Hydraulic Drills," *Proc. N.E. Inst. M. and M. Eng.*, vol. xxxvi. (1886–87), p. 67.

† C. B. Fox, "The Construction of the Simplon Tunnel," *Proc. Inst. C.E.*, vol. cxl., 1900, p. 258.

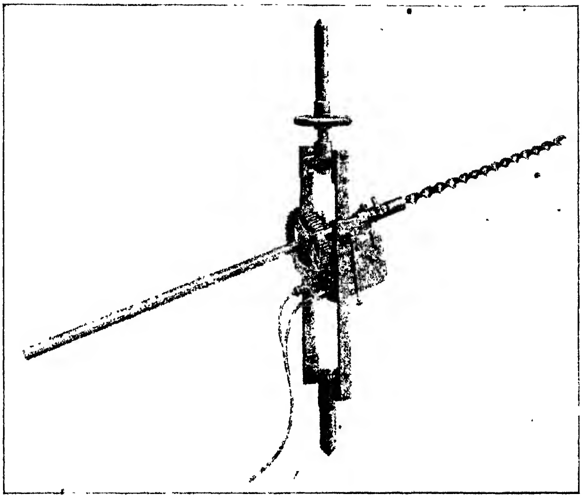


FIG. 78.—Jeffrey Electric Drill.

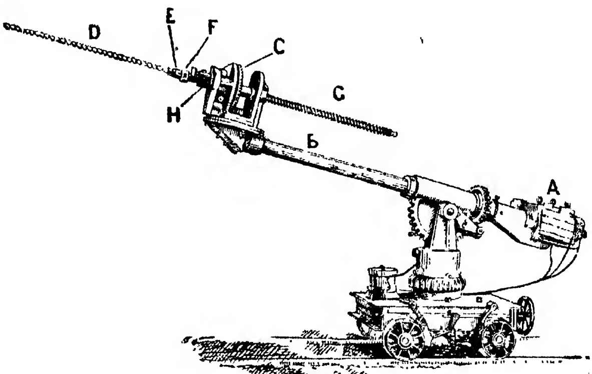
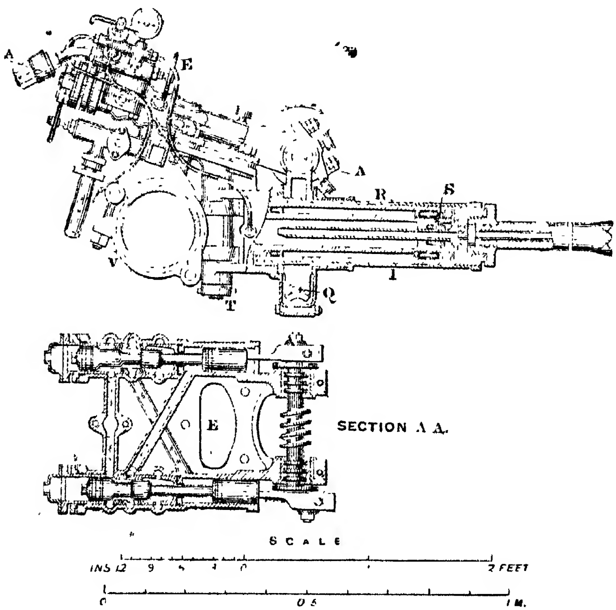


FIG. 79.—Steavenson's Twist Drill on carriage, worked by an electric motor.

shell; as the shell revolves it carries the ram around by the aid of a feather, whilst at the same time the ram is free to move forwards or backwards in the direction of its axis. The casing holding the shell is connected to the bed-plate of the motor by a vertical hinge and pin, T, and the whole is supported on a horizontal stretcher-bar by the clamp V. The bar is carried upon



FIGS. 80 and 81.—Brandt Hydraulic Drill.

a special carriage running on rails in the tunnel, and is jammed tightly against the sides by hydraulic pressure.

The actual drilling tool is a hollow steel tube armed with teeth, which, while it revolves, is kept tightly pressed against the bottom of the hole by water under a pressure of 30 to 80 atmospheres being let into the space in front of the piston S. At the same time the small central pipe (fig. 80) leads a stream of water to the very bottom of the hole; this washes out the debris and keeps

the tool cool. A very important feature of the drill is the prevention of dust, which is so exceedingly prejudicial to health.

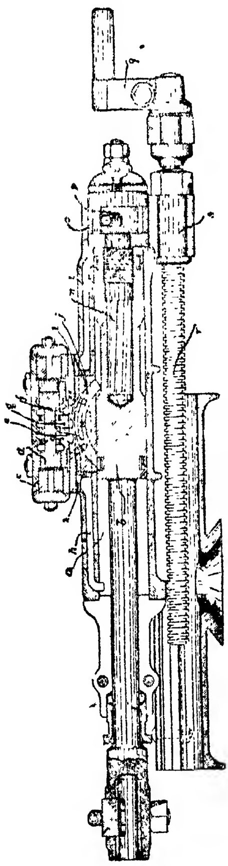


FIG. 82.—Ingersoll-Sergeant Drill.

The percussive drills are designed with a view of carrying out mechanically the two principal operations of hand work—viz., the blow and the rotation, whilst the advance is effected by hand. As a rule the percussive drill consists of a cylinder with a piston, which is moved backwards and forwards by compressed air or electrically; the cutting tool or chisel is either firmly fixed to the piston rod, or is hammered by it. The rotation is almost always effected by a twisted or rifled bar with a ratchet wheel; and, in order to keep the machine constantly in the proper position for work, it is fed forwards upon a cradle by the workman behind, who has merely to turn a handle, and so cause a screw to revolve inside a big nut attached to the machine.

In an elementary treatise it is quite unnecessary to do more than describe a few drills as types of the classes just mentioned, and I will first refer to three which are driven by compressed air.

The Sergeant drill has the peculiarity of having two valves, a main valve and an auxiliary valve; the latter is moved backwards and forwards by inclines or shoulders upon the piston; and, by controlling certain air-passages, it causes differences of pressure which drive the former.

In fig. 82, *a* is the cylinder, *b* the piston with an annular recess turned in it presenting two inclined shoulders; *c* is the valve-chest into which the compressed air enters from one

of the sides; *d* is the main valve, and as it moves to and fro it alternately places the port *e* or *f* in communication with the exhaust *g*; *e* leads to the port *h* and to the front end, and *f* to the port *i* and to the rear end of the cylinder; *j*, the auxiliary valve, is a slide valve made in the form of a segment of a circle, and having a recess in one of its flat faces. It is slightly longer than its arc-shaped seat, so that one end of it always projects into the cylinder. The projecting end of the valve is caught by the corresponding shoulder of the piston as it passes, and it is thus being constantly knocked backwards and forwards. By means of its recess this segmental slide-valve puts the ports *k* and *l* alternately into communication with the port *m*, which opens into the exhaust. The port *k* leads to the front end of the valve-chest, the port *l* to the rear end; consequently the two ends are being alternately placed in communication with the exhaust. The compressed air leaking past the piston-like ends of the main valve escapes into the exhaust at one end of the valve-chest, but exerts a pressure at the other end where it is confined, and so throws the main valve over, changing the direction in which the air is being admitted into the cylinder. The piston makes its stroke, knocks over the auxiliary valve, which in its turn releases the pressure at one end of the main valve and causes it to move across once more.

The rotation is effected by a rifled bar, *n*, as usual; but instead of there being a ratchet-wheel fixed to this bar with pawls outside it, as in fig. 85, there is a ratchet-wheel *o*, with internal teeth and a smooth exterior, the pawls being pressed out by springs, *p*. So far the action is very like that of other drills, save that the pawls move round inside the wheel, instead of the wheel moving round under the pawls. The special peculiarity of the Sergeant rotating device is the mobility of the wheel if the drill jams in a hole. The ratchet-wheel *o* lies loose in a recess behind the cylinder, and in ordinary working is pressed sufficiently firmly against the end of the cylinder, by steel cushion springs, to make the piston rotate without turning itself; but if for some reason the borer jams in the hole and causes a strain upon the rifled bar, the wheel is capable of turning and so preventing a breakage.

The feed as usual is by hand; *q* is the handle working the feed-screw *r* in the feed-nut *s*.

The Franke drill (fig. 83), in which the piston rod hammers upon the cutting tool, is the smallest and lightest boring

machine in actual use, because it weighs only 16 lbs., including the borer. Both in his drill and in his mechanical chisel, which will be mentioned later, Franke adopts the principle of doing the work by a light blow repeated frequently, instead of a heavy blow at less frequent intervals. The machine is practically a pneumatic hammer which strikes the head of the boring chisel. The borer is made of round steel $\frac{5}{8}$ inch in diameter, with a Z-shaped bit one inch wide. The number of blows has not been determined exactly, but it probably reaches 8000 to 10,000 per minute. The machine is used without

FIG. 83.—Franke Drill and Franke Mechanical Chisel.

any stand, and is simply held in the hands as shown in figure, in which the man in a kneeling posture is boring a hole for blasting by one of the little machines.

Among machines of the Hammer Action class may also be mentioned the Leyner drill, which has met with a considerable amount of success in Colorado. The piston, driven by compressed air, has a stroke of 3 in., and the end of the piston rod is continually hammering on to the end of the boring tool; this latter is held in a hollow chuck which is carried round by the piston rod when it rotates under the action of the usual rifled bar and ratchet-wheel. An important feature of the Leyner drill is the water flushing arrangement. A small

pipe conveys water from the rear of the cylinder right through the piston and piston rod into the chuck, whence it passes into the hollow drill; the consequence is that the bottom of the hole is kept clean and no dust is formed. This latter advantage is of the greatest importance from a hygienic point of view. Water under pressure is obtained from a small tank which is put into communication by a piece of hose with the compressed air main. The general appearance of the drill is shown in fig. 84. The small hose brings in the flushing water, the amount being controlled by a little handwheel. The large hose supplies the compressed air. A Leyner drill with a cylinder three inches in diameter weighs only 155 lbs.

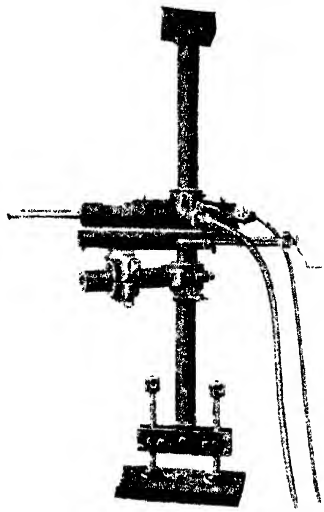


FIG. 84.—Water Leyner Rock Drill, Model 5, mounted on tunnel column.

The electric percussive drills in use at mines and quarries may be divided into two classes according as the tool is actuated by a solenoid or is driven mechanically.

The Marvin drill is of the former type, and its action is based upon the fact that a spiral coil of wire assumes magnetic properties when an electric current is passed through it, and becomes capable of attracting a bar of iron placed in a suitable position. The actual working parts of the drill are shown in fig. 85. A and B are two hollow coils of copper wire (solenoids) through which passes the rod or plunger C E D, a solid forging of soft steel. At the end C there is a socket for receiving the tool, whilst the end D is rifled and engages with a rifled rod attached to a ratchet-wheel, which effects the rotation in the usual way. A current is led to the drill by a cable with three wires, and by means of a very simple revolving armature on the dynamo,

it can be made to pass, first through one solenoid, and then through the other. Supposing that the current is passing

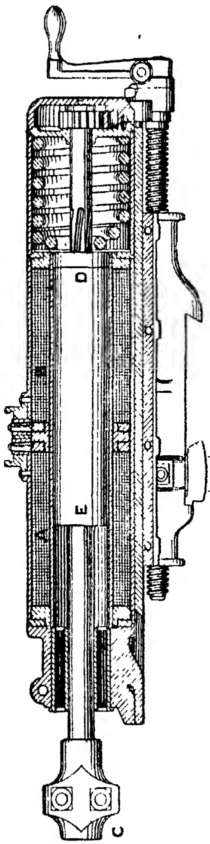


FIG. 85.—Marvin Electric Drill.

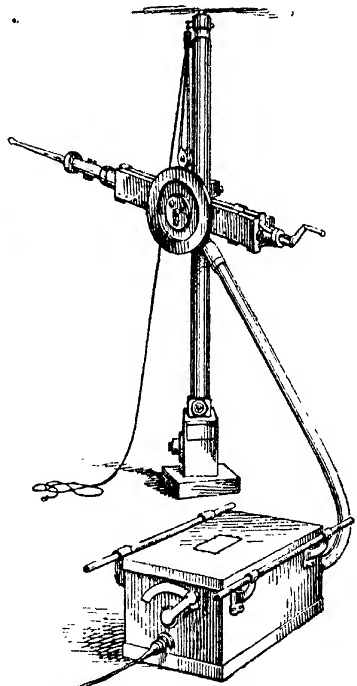


FIG. 86.—Siemens and Halske Electric Percussive Drill.

through the front solenoid, this becomes magnetic and draws the iron core forwards, and so causes the tool to strike a blow. The current is then reversed by the revolution of the

armature, and flows into the solenoid B, which in its turn becomes magnetic and draws the iron back, for A has lost its magnetic power. The rear end of the rod C D is made to compress a spring, and so store up force which is utilised in increasing the strength of the forward blow.

The drill, making 600 strokes a minute, is said to bore in granite at the rate of two inches a minute. It is in use in quarries, but, owing to its weight, it has not been much employed underground.

In the Siemens and Halske drill (fig. 86), the electric current drives a motor encased in a strong box placed upon the ground, the axle of which, by means of flexible shafting with suitable gearing and a crank, will impart a reciprocating motion to the drill holder. The Gardner drill is similar.

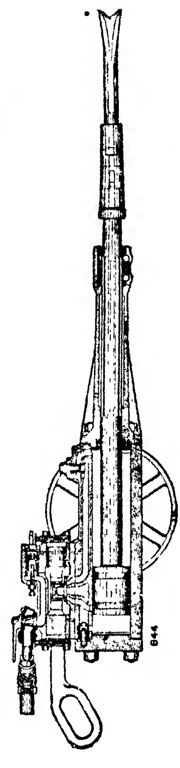


FIG. 87.—Sergeant 'Pick Machine.'

Groove Cutters.

The first machines for cutting grooves very naturally imitated the miner's tool, and were simply mechanical picks; but since then many other groove cutters have been invented which are based upon different principles.

They may be classified as follows:—

(*a*) Mechanical chisels and rock drills—*α*. Guided by hand. *β*. Travelling on bars. *γ*. Mounted on carriages running on rails.
(*b*) Circular saws or disc machines.
(*c*) Endless chains with cutters attached.
(*d*) Wire saws.
(*e*) Revolving toothed bars.

(*a*) Mechanical chisels, etc. *α* The Sergeant machine (fig. 87) is a strong rock drill with a chisel bit, which chips out a groove as a carpenter might cut out a mortice. The chisel does not rotate. The machine runs on two wheels and is directed at pleasure by two handles behind. The Harrison and Sullivan

FIG. 88.—Ingersoll Bar-channeller, Oakeley Slate Mine, North Wales.

machines are similar; they are all sometimes called 'punchers,' but more often, 'pick machines.' Franke's mechanical chisel (fig. 83) resembles his drill save that the rotating device is omitted. It is based upon the principle of striking a very large number of short and light blows, at least several thousand a minute, upon the chipping tool, and resembles some of the pneumatic caulking and sculpturing tools. It is employed at the Mansfeld copper mines.

β A groove may be made by boring a succession of holes immediately touching each other, or separated by small partitions which are broken off afterwards by a blunt chisel (*broach*). Most of the rock drill companies supply special quarry-bars or frames, upon which the ordinary boring machine can be mounted and made to travel, and thus cut a groove along any required line. Fig. 88 * shows the Ingersoll bar channeller in use at the Oakeley Slate Mine in North Wales.

γ The Wardwell Stone Channeller (fig. 89) is perhaps the best known machine in this subdivision of the class. It resembles a locomotive, as it moves upon rails laid down in the quarry; the steam engines which it carries lift jumpers up and down, and these cut vertical grooves as the whole machine propels itself along.

(*b*) Circular saws are largely employed for under-cutting coal, and they also render useful service in rock salt mining; they are often called 'disc machines.' A circular steel plate armed with removable teeth on its periphery is made to revolve by a bevel pinion with teeth gearing into slots on the disc. The pinion is driven by a pair of small compressed air engines or by an electric motor. As the pin round which the disc turns is supported by a thin bracket, the depth of the saw-cut may be made to approach the diameter of the disc. The machine is made to draw itself along by turning a drum and so coiling up a small wire rope one end of which is duly anchored. In this manner the machine will travel from one end of a long working face to another, and it is eminently suited for workings of this description.

(*c*) From the circular saw one passes very naturally to an endless chain armed with teeth. In the Jeffrey coal cutter (fig. 91) the chain travels round a frame shaped like an isosceles triangle. The base of the triangle is brought up against the face, and while the chain is travelling the whole frame is fed forward automatically. It makes a cut 44 in. wide, and when the cut has been carried in 5 ft., the frame

* From a photograph by Mr G. J. Williams, H.M. Inspector of Mines.

is withdrawn and the whole machine shifted sideways. It now makes a second cut adjoining and parallel to the first, and so on.

(*d*) The most novel method of cutting stone is one which is

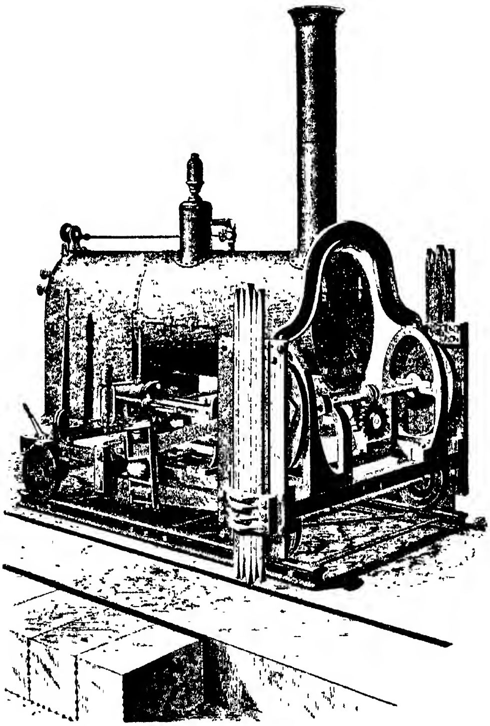


FIG. 89.—Wardwell Stone Channeller.

in use at marble quarries in Belgium, Carrara and elsewhere. It consists in sawing grooves by an endless cord, composed of three steel wires twisted together, which travels on the rock, and is supplied with sand and water.

Fig. 92 represents the arrangement adopted at the Traigneaux

Quarry, near Philippeville, Belgium. A, B, C, D, E, F, is the wire cord travelling in the direction shown by the arrows; G

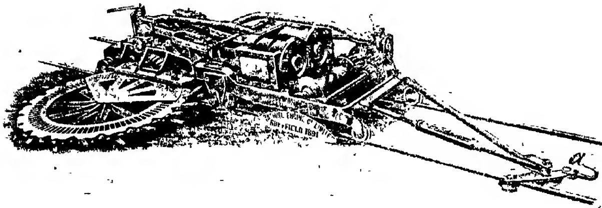


FIG. 90.—'Disc' Coal-cutting Machine of the Yorkshire Engine Co. Ltd.

and H are the two pits which have been sunk to hold the pulley frames. When the cutting process began, the wire cord would

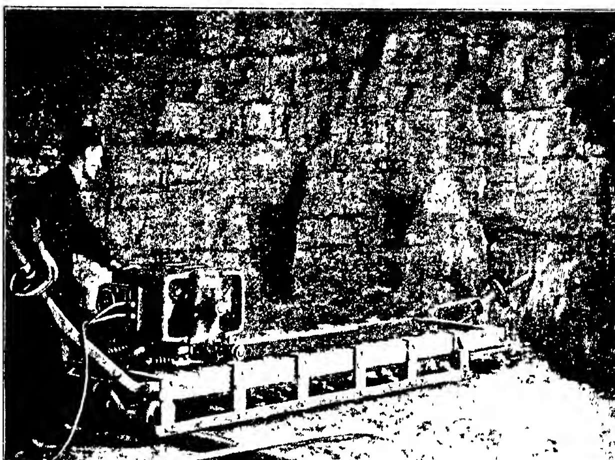


FIG. 91.—Jeffrey Chain Coal-cutting Machine.

have been running along the line I J; the groove is gradually deepened until it reaches the line K L. After suitable vertical

cuts have been made, the block is severed horizontally by means of wedges. Fig. 93 shows the kind of work done by the wire-saw at a slate quarry in the Pyrenees.

Monticolo has invented a penetrating pulley which will cut its way into the rock by itself: it allows the terminal pits to be replaced by small boreholes.*

(c) Hurd's coal cutter (fig. 94) is one of the latest forms of the revolving bar machines. In coal-cutters of this type a bar armed with teeth (fig. 95) is made to revolve by the aid of a

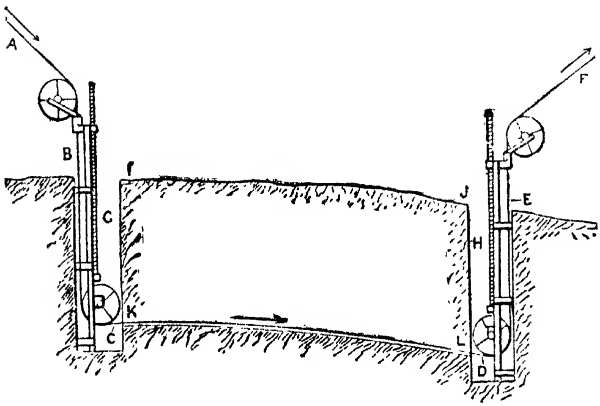


FIG. 92.—Wire Saw, Traigneaux Marble Quarry, Philippeville, Belgium.

compressed air or an electric motor, whilst the machine is hauling itself along the working face, in the same manner as a disc machine. The teeth on the bar cut a groove, the length of which is governed by the travel of the machine; like the disc coal-cutters, the bar machine is specially suited for long working faces. In Hurd's coal-cutter the bar can be placed so as to make the cut above or below the seam. Fig. 95 shows one of the replacable teeth.

* G. J. Williams, "On the use of the Wire-Saw for Quarrying Slate," Appendix IV. to C. Le Neve Foster's *Report on the Inspection of Mines in the North Wales, etc., District for the year 1900* London, 1901 [Cd 536-xii], p. 30.

Fig. 93.—Maillou Slate Quarry, Labassère, near Bagnères-de-Bigorre, France, where vertical and horizontal cuts are made by the wire-saw. The horizontal cuts in the picture are covered by rubbish.*

* From a photograph by Mr G. J. Williams, H.M. Inspector of Mines.

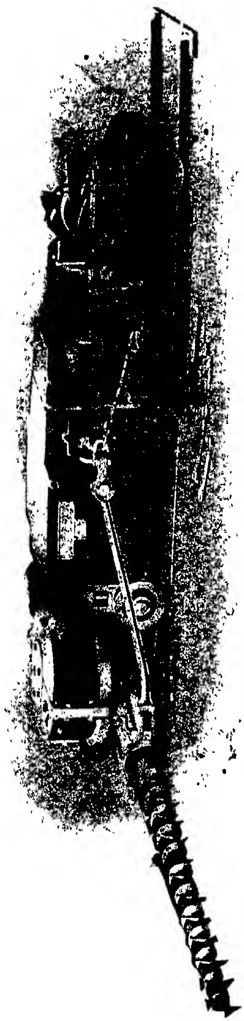


Fig. 94.—Hurd's Patent Electric Bar Coal-cutting Machine, arranged for under-cutting.

Tunnelling Machines.

A machine which will excavate a complete tunnel at one operation has long been a desideratum of the miner. Stanley's machine (fig. 96) cuts an annular groove in coal by teeth attached to a cross bar which is made to revolve by a compressed air engine. Much of the cylinder of coal within the groove breaks off while the cutting is going on, and what remains can easily be brought down by a single central blast.

Shaft-Sinking Machines.

In exceptional cases shafts are being sunk by the aid of machines which will cut out a big circular pit. As in the case of small holes, the work may be done by rotation or percussion. Rotary machines are being

employed in Germany in some sinkings through quicksand; the machines are big revolving scoops, and several ingenious contrivances have been designed for promoting the speed and success of the operations Large percussive tools similar in action to those employed in exploratory borings, enable shafts 16 ft. in diameter to be excavated through watery strata without any pumping being required, and the names of Kind and Chaudron will always be associated with this method of sinking.

Sutcliffe advocates the use of a machine which will cut a circular groove round the circumference of the proposed shaft, just as Stanley's machine cuts a groove for driving a level. When once a peripheral groove has been made, it is easy to blast away the core.

FIG. 95.—Replaceable Tooth or Cutter of Hurd's machine.

Driving Levels and Sinking Shafts by Rock Drills.—Where rock drills are employed the shot holes are not necessarily arranged in the manner they would be in the case of hand labour. Less attention, and sometimes no

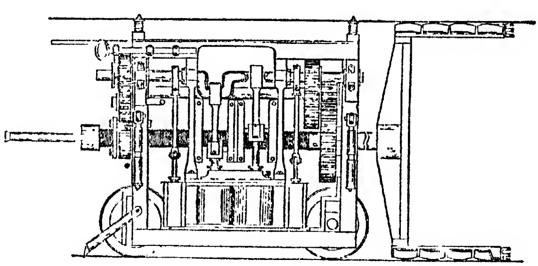
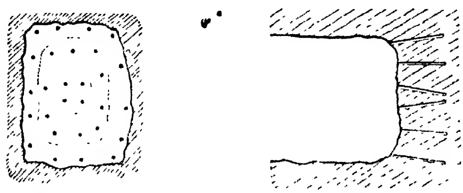


FIG. 96.—Stanley's Tunnelling Machine.

attention, is paid to natural joints, because the work is carried on according to a definite system certain of effecting the desired

result. It is true that more holes have to be bored than in the case of hand labour, but this is a matter of small importance. When once the drill is in its place a few extra holes can be bored with very little trouble, and the main considerations are certainty of action and speed of driving.

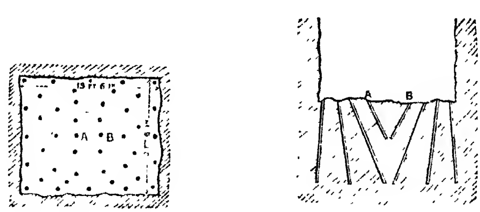
A common mode of driving in hard ground is shown in figs. 97 and 98. Four centre holes are bored about a foot apart at



FIGS. 97 and 98.—Method of placing bore holes when driving a level by machinery.

first, but converging till at a depth of 3 ft. they are within 6 in. or less of each other.

Other holes are then bored around them until the end is pierced by twenty or thirty holes in all. The four centre holes are charged and fired simultaneously, either by electricity or by Bickford's instantaneous fuse, and the result is the removal of a large core



FIGS. 99 and 100.—Plan and section showing method of placing boreholes when sinking a shaft by machinery.

of rock. The holes round this preliminary opening are then charged and fired, generally in volleys of several holes at a time, and the level is thus carried forward a distance of 3 ft. If large holes are bored, and if the ground is more favourable, fewer will be required.

In the case of shafts the method of procedure is similar.

Figs. 99 and 100 are a plan and section of a shaft which was

sunk at the Foxdale mines in the Isle of Man. About forty-five holes were drilled at the bottom of the shaft before the drills were removed. Two of the holes (A and B), and occasionally four, were bored only 4 ft. deep, and were blasted with ordinary fuse. They simply served to smash up and weaken the core; then the six holes nearest the centre, which were 8 ft. deep, were blasted all together with Bickford's instantaneous fuse, and the result was the removal of a large core, leaving a deep 'sink.' The remaining holes were fired in volleys of four at a time in the ordinary way.

(3) Special Methods of Excavation.

These are three in number, viz., by heat, by solution, and by a jet of water.

Though hard ground is almost invariably nowadays attacked by boring and blasting, the very ancient process of fire setting is not quite obsolete. The effect of a fire is to make a rock split and crack, and render it easily removable by the pick or by wedges. Before blasting was known, fire setting was largely employed; but its use is now confined to a few places where the rocks are exceedingly hard and where wood is abundant and cheap. Piles of wood are heaped up against the face of the working and set on fire. On returning to the working place after the rocks have cooled a little, it is found that the ground has split and flaked off, and that much is loose enough to be worked away by the pick and wedge.

In the exceptional case of frozen strata, such as are found in Siberia and the Klondike region, fire is employed as a thawing agent. Billets of wood are placed upon the site of the proposed shaft and lighted; the heat softens the frozen soil, and makes it easy for the miner to excavate his pit for a few inches; by repeating the process, he eventually sinks down to the auriferous bed. Pursuing his drivages along it by the same method, the Klondike miner gets out a store of gold-bearing gravel. Another method of thawing is to use steam. A boiler is erected at the surface, and steam is conveyed close to the working face by a pipe to which is attached some flexible hose. One end of the hose is provided with a short piece of iron pipe with a small hole at the end. The pipe is pressed against the frozen strata, and the warmth of the issuing steam soon enables it to be pushed in for 3 ft. or so. It is then left, and after the lapse of a few hours the ground around it for a distance of some feet is thoroughly thawed and rendered loose.

Soluble minerals of economic value are not very common. The

FIG. 101.—Hydraulic Mining, Cariboo, B.C.

dissolving process is applied particularly in the case of getting salt, not only in this country, but also in Austria, Germany and Switzerland. In the Austrian Alps there are thick beds of saliferous marl, and the process of working the deposit consists in excavating large chambers and bringing in water. The salt is dissolved and the brine is piped away to be evaporated.

A big jet of water under pressure forms a very powerful excavating agent for comparatively soft strata, such as beds of gold- or tin-bearing gravel; and very considerable use is being made of this process, often known as hydraulic mining, in the United States, Canada, Australasia, the Federated Malay States and elsewhere. Fig. 101 represents two gigantic nozzles or 'Monitors,' from which are issuing huge jets of water; these are washing away gold-bearing alluvial gravel. The height of the bank from the bottom of pit to the top is 300 ft. and sometimes more.

In fig. 102 the rock which is being washed away is decomposed auriferous slate, and not gravel.

The pressure is obtained naturally or artificially. It is especially in California that huge reservoirs have been constructed for the purpose of impounding large volumes of water at suitable elevations above the gold beds to be worked. It is often impossible to do this without going to a distance, and then the water has to be brought to the workings by means of ditches, troughs (*flumes*) (fig. 103*) or pipes.

The water-course terminates in a box, whence a big pipe is carried close to the bank of gravel to be excavated; a movable nozzle enables the jet to be directed as required.

If no natural fall exists within a reasonable distance, steam pumps can be made to raise the water into a reservoir, or to deliver jets of water directly (*vide* also Chap. VI.).

* Brook, "Notes from the Atlin District, British Columbia," *Eng. Min. Journ.*, vol. lxxiv., 1902, p. 707.

Fig. 102.—Hydraulic Mining, Singleton Mine, Dahlonega, Georgia, U.S.A.

FIG. 103.—Flume for Consolidated Spruce Creek Placers, Atlin District, B.C.

CHAPTER V.

SUPPORT.

EXCAVATIONS made in hard ground will frequently stand without any props whatever for an unlimited time, but the miner has generally to deal with rocks which sooner or later give way unless supported. The ordinary methods of support will first be dealt with, and in conclusion certain special methods will be described briefly.

The common modes of securing mining excavations may be classified according to the materials used, viz., timber, masonry, iron or steel.

(1) Timber.

For reasons of economy, the miner naturally obtains his timber from forests in the neighbourhood if possible, and when obliged to resort to other districts or other countries for supplies, his choice depends largely upon the cost of freight.

I will briefly point out some of the principal kinds of timber used in the five quarters of the globe.

Europe possesses many useful conifers such as the larch (*Abies larix* or *Larix Europæa*), Scotch fir (*Pinus sylvestris*, L.), and Silver fir (*Abies pectinata*, D.C.). On the Mediterranean one finds the maritime pine (*Pinus maritima*) and the stone pine (*Pinus pinea*). The spruce fir (*Abies excelsa*, D.C.) is far less suitable than larch or Scotch fir, and should not be employed where great strength or durability is required.

Of the broad-leaved trees, the oak (*Quercus robur pedunculata* and *Quercus robur sessiliflora*) has long claimed the first place for durability and strength. In wet places its claims are justified; on the other hand, in the dry bad air of some mines it has to yield the palm to the acacia * (*Robinia pseudo-acacia*). This is a tree deserving the special attention of the miner, as it can be grown

* Kausch, "Akazienholz (Robinien) als Zukunftsholz fur den Bergbau," *Gluckauf*, vol. xxxiv., 1898, p. 842; *Ibidem*, vol. xxxv., 1899, p. 204.

upon very poor soil and is capable of yielding useful props after the lapse of twenty to twenty-five years.

Beech (*Fagus sylvatica, L.*) though in no way equal to oak or larch, has been too much neglected by the miner. The colliery owners of Northern France find it profitable to employ alder (*Alnus glutinosa*), aspen (*Populus tremula*), birch (*Betula alba*), cherry (*Cerasus communis*), and hornbeam (*Carpinus betulus*) for supporting purposes, in addition to pine and oak.

In Northern Asia the miner finds stores of pine ready for his use, and judging by the long lists of trees mentioned by Mr James Grundy * and Dr F. H. Hatch † there is no lack of suitable pit timber in India. For all special work such as shaft frames, where durability is all-important, teak (*Tectona grandis*, Linn.) is employed with advantage. The principal kinds of timber used in the Mysore mines are Urupu (*Hopea parviflora*, Bedd.) and Irul (*Xylia dolabriformis*, Benth.).

The most important mines of Africa are in the southern part of the continent. I learn from my friend Prof. Lawn, of Kimberley, that native timber is used to some extent in the diamond mines. The commonest kinds are named in the table below.

NATIVE TIMBER USED AT KIMBERLEY DIAMOND MINES.

Miner's Name.	Popular Name.	Botanical Name.
Yellow Wood. ‡	Outeniqua Yellow Wood.	Podocarpus elongata.
	Upright ,, ,,	,, latifolia
Pear Tree. §	White Pear.	Apodytes dimidiata.
	Hard ,,	Olinia cymosa.
	Mountain ,,	Cathastrum Capense.
Iron Wood. ‖	Black Iron Wood.	Olea laurifolia.
	White ,, ,,	Toddalia lanceolata.

Speaking generally, the rocks of the South African goldfields are hard and require but little timber for the purpose of support. Among the home-grown timbers used for props may be mentioned black wattle (*Acacia decurrens*) and blue gum (*Eucalyptus globulus*).

* *Report on the Inspection of Mines in India for the Year ending 30th June, 1895*, Calcutta, 1896.

† "The Kolar Goldfield," *Mem. Geol. Survey India*, vol. xxxiii., Calcutta, 1901, p. 58.

‡ Much used underground.

§ Used underground.

‖ Used underground, but not so much as yellow wood and pear tree.

Canada and the United States, though gradually losing some of their enormous wealth in timber, are still well supplied with many kinds of conifers suitable for mining purposes. The Douglas pine (*Pseudotsuga Douglasii*, Carr.), often called Oregon pine, is exported in large quantities to Australia and the Cape. It is a beautifully straight grained, readily worked wood: but it easily takes fire and has been the cause of serious underground conflagrations, especially at the Broken Hill mines in New South Wales.

Our Australian colonies are specially marked by being the home of various kinds of eucalyptus. Two that are particularly durable are jarrah (*Eucalyptus marginata*) and karri (*Eucalyptus diversicolor*), which have been employed for shaft frames.

Iron bark (*Eucalyptus crebra*, F. v. M., and *Eucalyptus leucoxylon*, F. v. M.), is a name given to more than one species of eucalyptus used at mines.

New Zealand boasts of the magnificent Kauri pine (*Dammara Australis*), which is far from being its only mining timber; and parts of Tasmania, owing to their moist climate, are well supplied with forests.

Timber may be affected both by animal and by vegetable pests. In this country a considerable amount of damage has been done to mining timber by two boring insects—the wood wasp (*Sirex gigas*) and the steel blue (*Sirex juvencus*)—which continue their ravages even after the props or frames have been placed underground.

Some collieries in Germany have been troubled by a small weevil which weakens the props, or indeed renders them quite useless by its indefatigable burrowing propensities. The white ant, the great enemy to wood in the tropics, will attack many kinds of timber in dry parts of mines, and countless hordes of this winged pest are sometimes seen in the parts of shafts above the adit level, ready to carry on their destructive labour and speedily force the miner to put in a new lining.

The ravages of animal pests, however, are not to be compared in amount to those of the vegetable organisms which produce the decay known as 'dry rot.' The spores of a fungus alighting upon the mine timber give birth to a white feathery plant which spreads over the surface, or hangs down in long festoons in places where there is no traffic. To use a common expression, the fungus "saps the vitals" of the timber. In the course of a few years or even months, hard wood becomes converted into soft tinder on the outside, and the decay proceeds insidiously, until at last the prop is utterly incapable of supporting its load and gives way under its burden.

Much may be done by the miner to counteract the two kinds of baneful influences just mentioned. Felling at the proper season, when the trees have the least amount of sap, and ample seasoning, will greatly increase the life of timber; and its resistance to animal and vegetable destroyers may be further increased by various preservative devices. Among these may be mentioned, soaking the timber in, or completely impregnating it with, antiseptic metallic solutions such as common salt, sulphate of iron, etc., and chloride of zinc. Painting the timber with a tarry liquid, known as 'carbolineum avenarius,' is a remedy well spoken of in Germany. The 'solignum' and 'jodelite' of this country are similar to carbolineum. The expense of using a good preservative is generally fully repaid by the decreased cost of repairs.

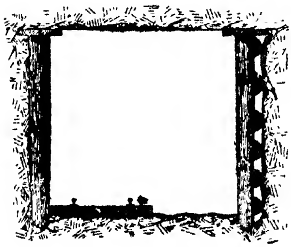


FIG. 104.*—Timbering in a level with a strong roof.

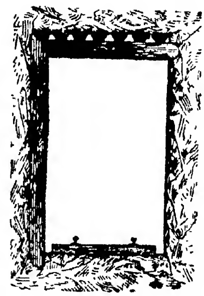


FIG. 105.*—Timbering in a level with roof and one side weak.

In addition, there is sometimes greater security to the miner, owing to the inflammability of the timber being diminished by the treatment.

Timber is used in various forms; the trunk is sometimes merely sawn into pieces of suitable length, or it may be hewn or sawn into square balks, or sawn in half, or into planks of different thicknesses.

The tools used by the miner for shaping the timber are the saw and axe; in addition he requires a measuring staff, a sledge or a wooden mallet for driving the timber into its place, a hammer and a 'moil' for chipping out recesses or niches (*hitches*), a plumb line and a level.

The principal kinds of excavations in mines are levels, shafts and

* *Die Verhandlungen und Untersuchungen der Preussischen Stein und Kohlenfall-Commission*, II Heft., Berlin, 1902, pp. 192-199.

working places. The methods of timbering a level vary considerably, because the parts requiring support may be either the roof alone, or the roof and one or two sides, or the roof, sides and bottom.

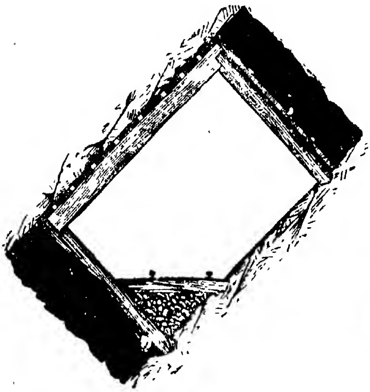


FIG. 106.*—Timbering of a roadway in a coal seam.

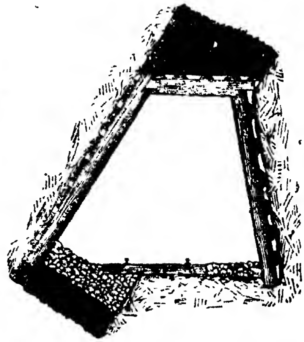


FIG. 107.*—Timbering of a roadway in a narrow seam.

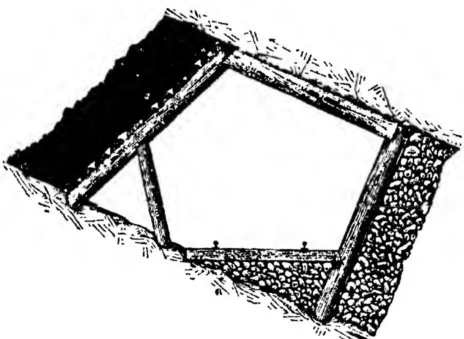


FIG. 108*—Timbering of a roadway in a coal seam.

If the roof is strong, props with lids may suffice to keep it from falling (fig. 104). Fig. 105 shows a case in which the roof and one

* *Op. cit*

side require support. In fig. 106 the seam of coal is fairly thick and the excavation affords room enough for a roadway; but in fig. 107 the seam is thinner and part of the side has to be cut away in order to obtain the necessary space The pressure of coal may be so great that some of the pieces of timber may require struts to prevent them from yielding (fig. 108). Where the floor of a level is soft and weak, a sole piece or *sill* becomes necessary.

In some large veins in Queensland, with very considerable roof

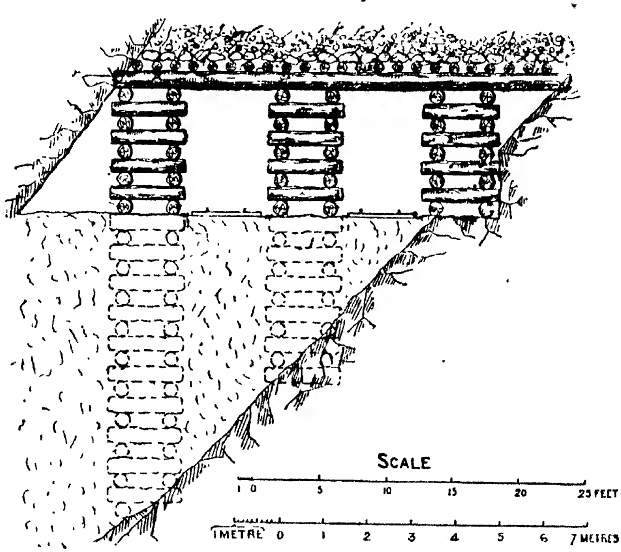


FIG. 109.— 'Chocks,' 'Cogs,' or 'Pigsties.'

pressure, the upright supporting pieces have been replaced with advantage by hollow square pillars built up of logs placed two by two crosswise. These columns, either left hollow or filled with rubbish, and known as *chocks* and *cogs* in this country, and as *pigsties* in Australia (fig. 109), have far more elasticity than a single prop, and offer a greater supporting area. This method of support requires a great deal of timber, but it has the advantage that small logs are inexpensive and easily handled.

The timbering required for shafts varies according to the

nature of the ground and the size of the excavation. A mere lining of planks set on their edges and checked together (fig. 110) suffices for small shafts, corner-pieces being nailed on so as to keep the successive frames together.

The usual method of securing shafts is by *sets* or *frames*. Each set consists of four pieces—two longer, called *wall-plates*, and two shorter ones, called *end pieces*. They are joined by simply halving the timber at each end as shown at fig. 111. A more complicated joint (fig. 112) is often preferred. The separate frames are kept apart by distance pieces (*studdles*, Cornwall; *jogs*, Flintshire; *posts*, United States), and loose ground is prevented from falling in by boards or poles outside.

When the end-pieces carry the wall plates they are sometimes made long enough to project a foot or 18 in. beyond them, and rest in niches in the rock. During the process of sinking, the last frames are temporarily hung from those above by strong clamps, and

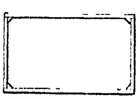
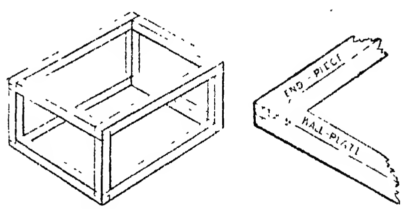


FIG. 110.—Timbering for a small shaft.



FIGS. 111, 112.—Timbering for shafts.

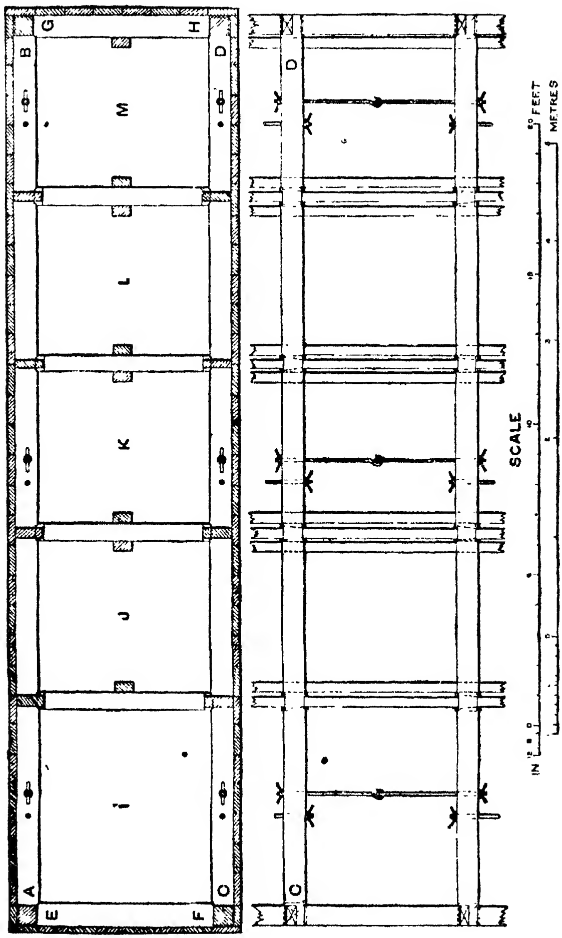
when a length of 10 ft. or 12 ft. has been completed, planks (*lashings* or *listings*) are nailed on inside, stretching over several frames and so binding them together.

This lining of the shaft may be regarded as a very long box, with strengthening ribs at short intervals. As shafts are frequently used for the several purposes of pumping, hoisting, and affording means of ingress and egress by ladders, it becomes necessary to divide them into compartments. Pieces of timber parallel to the end-pieces (*buntons* or *dividings*) are then fixed across the shaft; and they serve not only to carry the upright partition of planks (*brattice*) between two adjacent compartments, but also to stay the wall-plates, to hold the guides or conductors, and to support platforms, which are necessary for ladderways and for the persons attending to the pumping machinery.

Figs. 113, 114 and 115 * explain the method of timbering

* Largely based upon drawings kindly supplied by the Consolidated Goldfields of South Africa, Ltd.

adopted in many of the large shafts at the gold mines of the Witwatersrand.



Figs. 113 and 114.—Plan and elevation showing the timbering of a five-compartment shaft in the Transvaal.

A B and C D are the two wall-plates, E F and G H the two end-pieces; the long oblong space contained by them is divided into five compartments, I, J, K, L, M, by four cross timbers or 'dividers.' Four of these compartments are used for winding purposes, and are fitted with guides fastened to the dividers. The fifth compartment serves for ladderways, pumps and air-pipes. Between each two successive shaft frames there are four corner posts, frequently called studdles, and eight smaller subsidiary distance pieces, also known as studdles. Each frame is suspended by bolts from the frame above, and the lining of planks, shown

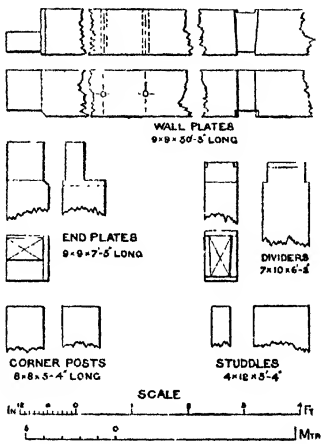


FIG. 115.—Details of the joints of the timbering.

in fig. 113, prevents any pieces of rock from falling into the shaft.

The timbering of working places varies greatly. The simplest case is that of a horizontal bed, when props put in vertically will often suffice to support the weight of the roof. The addition of a *lid*, a flat or slightly wedge-shaped piece of board, extends the bearing surface, and, by presenting a smooth face to the top of the prop, enables this to be forced more firmly into position than it could be against a rough roof. It also yields a little to the pressure of the roof, and lengthens the life of the prop in this way. If the bed is inclined, the prop is set somewhere

between the normal to the roof and floor, and the vertical line.

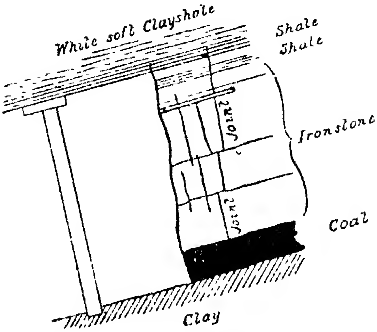


FIG. 116.—Prop and lid, Staffordshire.

Fig 116, copied from Mr Sawyer,* is an instance of a prop and lid for working in a bed of clay ironstone. The illustration † in

FIG. 117.—Prop and lid, alluvial gold mine, Western Australia

fig. 117 is a photographic representation of the same method of

* *Accidents in Mines from Falls of Roof and Sides*, London, 1886, p. 50.
† From a photograph taken by Messrs Joshua & Dwyer, Kalgoorlie, and kindly supplied by Mr A. G. Charleton, A.R.S.M.

support. The chocks, cogs, or cribs already mentioned form very efficient supports and are largely used in working places. The logs employed in building them vary in length from 3 to 20 ft.

Fig. 118 represents one of the huge structures which may be seen in the Wieliczka salt mines.

The 'square set' system, largely used in the United States and Australia, and not unknown in this country, has been devised for supporting the roof and sides of the excavations which are formed in working away large irregular ore-bodies and very wide veins. It consists in filling the worked-out space with a timber structure, built up of a series of parallelopipedal frames. Each 'set,' or unit of the structure, is identical in shape and size, and is composed of a rectangular base placed horizontally, formed of four pieces of timber 4 to 6 ft. long, carrying a post 6 to 7 ft. high

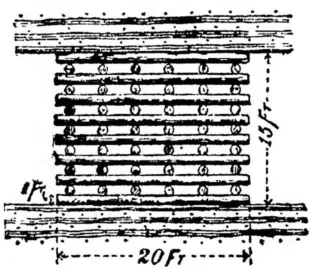


FIG. 118.—Timber structure for supporting the roof, Wieliczka, Austria.

at each corner, and capped by a rectangular frame similar to the base. The cap-pieces which form the top of any set are at the same time the base of the next set above. As all the tenons and shoulders for jointing are cut at the surface strictly to gauge, the building up of the framework can be made to follow the removal of the ore with great ease and speed.

This system has the disadvantage of introducing into the mine a huge inflammable structure, which is a source of great danger.

(2) Masonry, Brickwork, etc.

Masonry has long been used for supporting purposes in mines. The materials necessary are stone, ordinary bricks or slag-bricks, and they may be built up alone (*dry walling*), or with the aid of mortar or hydraulic cement. Concrete, a mixture of hydraulic

cement, sand and small stones, is occasionally employed, and undoubtedly could be more so with advantage.

In levels, dry walling and timber are sometimes combined.

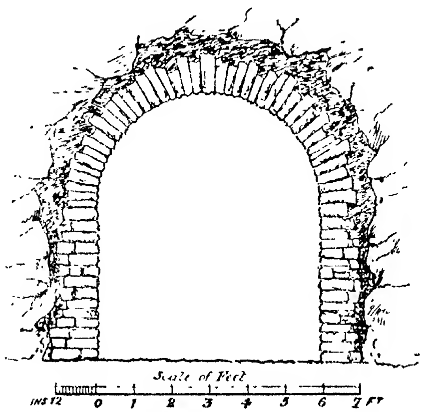


FIG. 119.—Level lined with masonry, Forest of Dean.

Thus, after the excavation of a wide lode, the rubbish is piled up on the sides, walls are built up of the large stones, and beams of timber are laid across, which support the 'deads' when the higher portions of the lode are taken away.

Fig. 119 represents a level in an iron mine in the Forest of Dean, lined with roughly hewn sandstone.

If both sides of a vein (fig. 120) are firm, an arch affords ample protection when the mineral has been removed, and provides a resting-place for the rubbish (*deads*, *attle*).

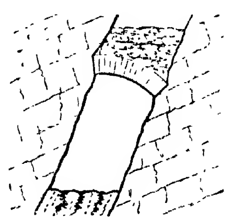


FIG. 120.—Stone arch in roof of a level.

Steel girders are sometimes employed as an adjunct in dry walling. In fig. 121 the sides are built up with stone for a thickness of 16 in., whilst the roof is made of a succession of curved beams of I-steel 2 ft. 6 in. apart. The spaces between the successive beams are partly covered over by

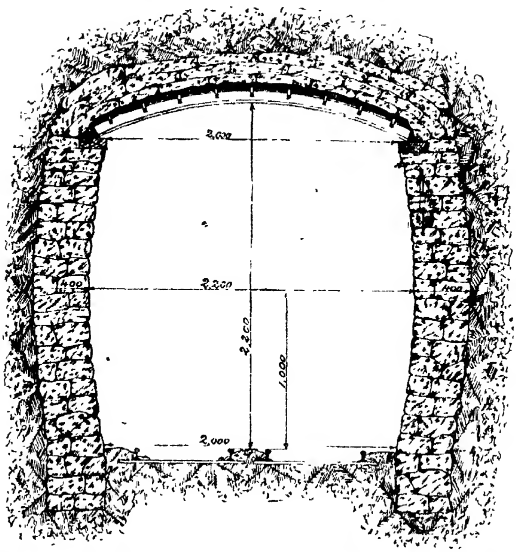


Fig. 121.—Wide roadway with lining of dry walling, steel beams and rods.*

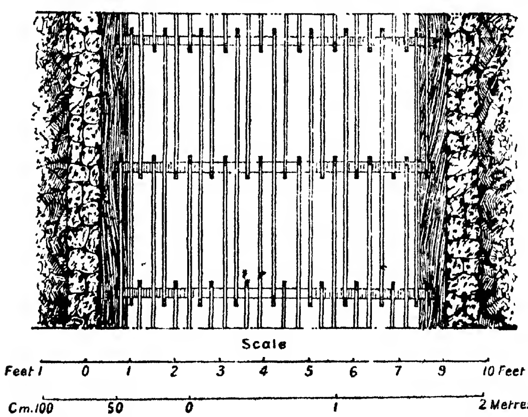


Fig. 122.—Plan showing the small rods stretching from beam to beam.

* From a drawing kindly supplied by the Director of the Marles Collieries, Pas-de-Calais, France.

small rods of square iron (*Queues Daburon*, Fr.), and the arch is then completed with pieces of flat stone as shown.

One of the main cross cuts at Mansfeld was lined with concrete for a length of 1000 metres (·65 mile); 12 metres (40 ft.) a day were put in, and for this purpose 50 metres (164 ft.) of centering were required. The laths were covered with thin sheet iron, so as to prevent the concrete from sticking. The concrete was made of Portland cement, broken stones and gravel, in the proportion of 1 to 7, viz., 1 part of cement, $2\frac{1}{2}$ of broken stone, and $4\frac{1}{2}$ of gravel. Up to a height of 1′6 in. from the ground, the layer of concrete was made thick enough to join on to the sides of the level, in order to assure a firm foundation. Above that height it was made only 6 in. thick, the sides of the level having been previously built up with dry walling.

In the case of shafts, the advisability, or indeed frequently the necessity, of having a lining which will be permanent and require few repairs, is very marked. The shaft is generally the main thoroughfare leading to the workings; in a coal-mining country like England, it constantly happens that a couple of shafts form the sole outlets for the men and the mineral, and the sole passages for the entry and exit of the necessary air supply. If the lining of one of the shafts were to collapse, the lives of the pit's crew might be imperilled by a stoppage of the ventilation and the whole work of the mine brought to a standstill. The seam-miner, who is able to estimate the number of years his pits will be wanted, and who sinks far fewer shafts than the average vein-miner, finds it to his advantage in every way to use a form of lining which to the latter has often seemed extravagant.

In addition to being more durable, the lining of bricks, masonry or concrete has the immense advantage of being non-inflammable. It is true that many shafts are wet, and consequently free from any danger of the timber lining taking fire accidentally; but sundry terrible shaft-fires at home and abroad, causing great loss of life, have led to the opinion among capable mining engineers that the linings and fittings of all shafts should be made of fire-resisting materials, unless the shaft is damp naturally or kept wet artificially.

The section of walled shafts is generally circular, as affording the best resistance to pressure. Elliptical walling is chosen by some mining engineers when it is necessary to provide room for pumping as well as for two cages. The oval is sometimes struck out by two segments of a circle of large radius for the sides, and two segments of a circle of short radius for the ends. The walling may be dry or with mortar according to circumstances.

The masonry lining is put in either in one length, or in successive rings or sections in descending order, and this is the usual plan.

The shaft is sunk to a certain depth with a temporary lining of timber, and when firm ground has been reached, a bed is cut out on which is placed a crib or curb (A B, fig. 123),* consisting of segments of timber forming a ring. This serves as a foundation for the brickwork, which is built up to the surface; the temporary timbering is sometimes left in and sometimes removed as the work progresses, and any vacant space is filled in with earth or concrete. Sinking is then resumed, and of a smaller diameter for a certain distance, so as to leave a bracket or ledge to support the curb. On arriving after a certain depth of sinking at another firm bed, a second curb, C D, is put in, and a second ring of brickwork built up. When the intervening ledge of rock is reached, it is carefully removed in small sections, and the brickwork brought up to the first curb. This process is repeated until the shaft is completed, or reaches rock in which no masonry is required. If, owing to the nature of the ground, it is impossible at first to find firm seats for the curbs, they must be hung by iron bolts from a strong bearing frame at the surface, or from iron pins fixed in the sides.

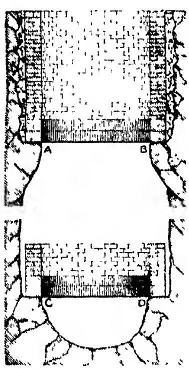


FIG. 123.—Brick lining for shaft.

Some shafts in Germany have lately been lined with concrete blocks shaped so as to fit the curvature of the sides. Each block is fluted at the top and at the ends, whilst the bottom has a beading, which lies in the channel of the block below it. A simpler plan is to build up a concrete lining between the sides of the shaft and suitable centerings. The Monier system consists in strengthening the concrete by a coarse network or skeleton of iron wire embedded in it. The ingenious iron lattice-work of the Expanded Metal Company, which has been successfully employed in reinforcing concrete for building purposes, might likewise be employed.

Ordinary working places are mere temporary excavations, and it is only in exceptional cases that it is possible to incur the expense of building pillars with cement or mortar to support the roof and sides. Rough pillars, built up of lumps of waste stone

* J. Callon, *Lectures on Mining*, vol. i., Atlas, Plate XXVIII.

or of the useful mineral itself, may sometimes take the place of timber or may be used as adjunct to it, as is the case in fig. 124, borrowed from Mr Sawyer.* The timber at the top allows the pressure to come gradually upon the stone. The post is eventually drawn out and the stone recovered.

(3) Metallic Supports.

There are various ways of employing iron and steel as supports for levels, shafts and working places.

Some neat and effective forms of steel supports are made in

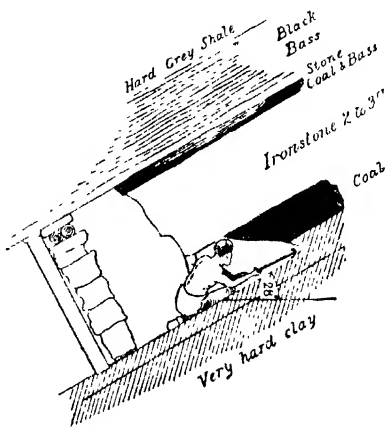


FIG. 124.—Stone pillar supporting the roof of a working place, Staffordshire.

France, where more attention has been paid to the subject than in this country. Where the floor of a level is good, frames such as are shown in fig. 125 answer admirably; where the surrounding conditions are liable to cause the floor to rise (*creep*), a circular frame affords support all round (fig. 126).

The supporting frame shown in fig. 127 † is made of rails or I-steel. The horizontal bar is connected by bolts to the pieces of angle steel which are riveted to the legs; but it is not uncommon to see a steel bar supported by wooden legs which are capped with

* *Op. cit.*, fig. 4.

† *Die Verhandlungen und Untersuchungen der Preussischen Stein- und Kohlenfall-Commission*, II. Heft., Berlin, 1902, pp. 192 199.

some form of cast or wrought-iron shoe (fig. 128 *). If the roof pressure is great, or the span wide, the bar is often slightly arched (fig. 129*).

The advantages of using iron or steel supports instead of timber are numerous:

(1) Greater durability, which means a reduction in the cost of repairs.

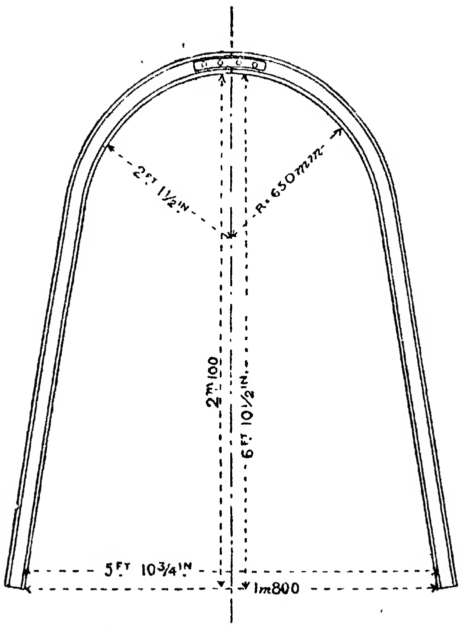


FIG. 125.—Steel supports for levels.

(2) Possibility of using the beams elsewhere when taken out. If bent slightly, they can be reversed; if badly knocked about they can be sent to the steel works and worked up again. In any case, they are of some value.

(3) Lightness and handiness compared with timber.

(4) Increased space for ventilation. The free space in a level

* *Die Verhandlungen und Untersuchungen der Preussischen Stein- und Kohlenfall-Commission*, II. Heft., Berlin, 1902, pp 192–199.

will be from 5 to 7 in. higher with steel than with timber in lining an excavation of a given size. Six inches added to a

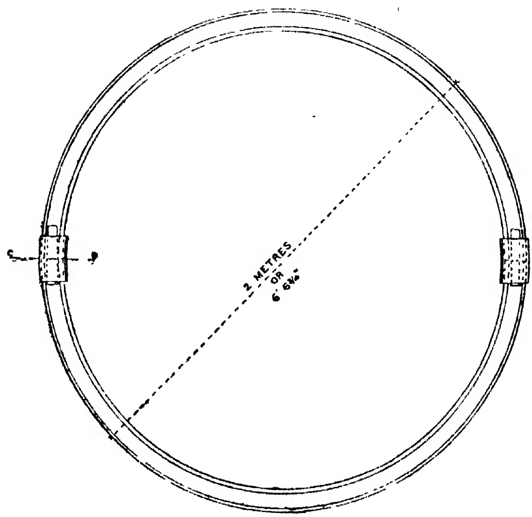


FIG. 126.—Circular steel frame for levels.

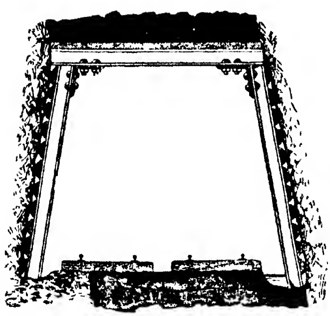


FIG. 127.—Steel beams for supporting roof and sides of a level.

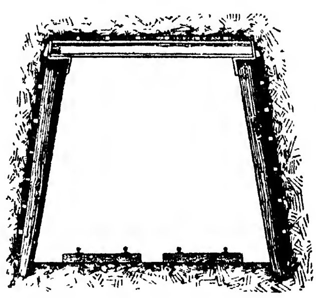


FIG. 128.—Steel beam resting upon timber 'legs.'

height of 6 ft. means an increase of $\frac{1}{12}$, or $8\frac{1}{2}$ per cent., in the area of the airway.

(5) No deterioration of the air of the mine by decaying timber.

(6) No danger from fire.

The 'lagging' outside the frames may be composed of planks or of thin bars of square iron or channel iron.

Large and small shafts are now very successfully lined with circular or rectangular supporting frames made of steel. The circular frames are rings of channel iron or steel, made in two or three segments bolted together inside.

Figs. 130 and 131 show the nature of steel lining in a shaft sunk a few years ago at Clausthal in the Hartz.*

Steel has lately been employed for the purpose of lining inclined shafts at large iron mines in Michigan. At B shaft, Pioneer Mines,

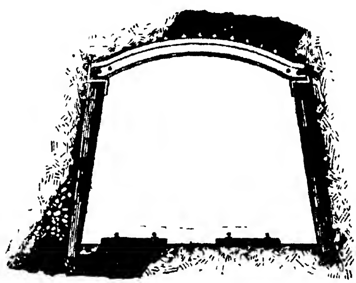


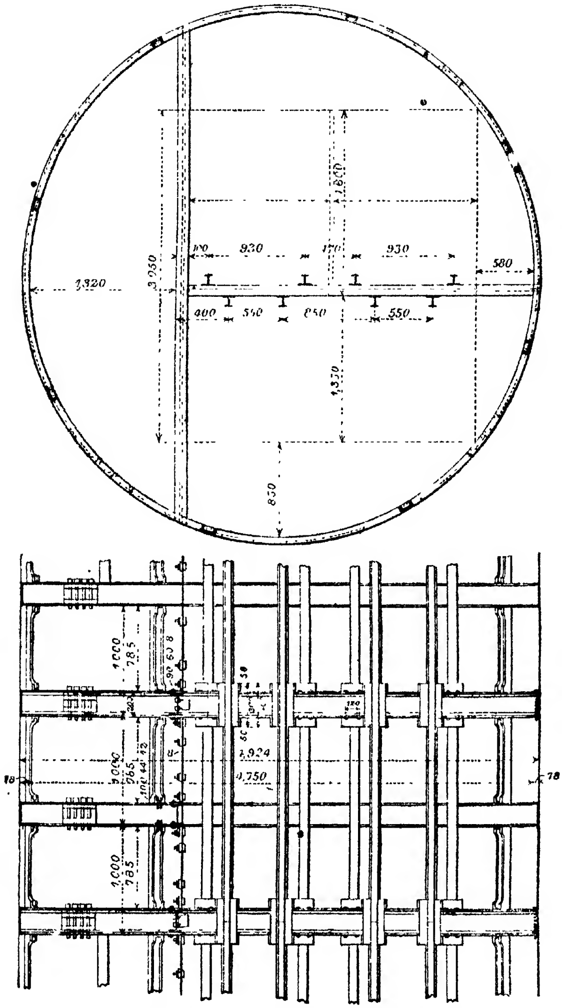
FIG. 129 Arched steel beam resting upon timber 'legs.'

Michigan, the inside dimensions of which are 17 ft. 6 in. by 6 ft., the two wall-plates are made of 30-lb. steel rails, and the end-pieces of 25-lb. rail. These are held together at the corners by pieces of angle steel riveted on with half-inch rivets. The rails for two skip-ways are supported by dividings made of I-steel. The successive frames are kept apart by studdles, also made of rails. Figs. 132, 133, and 134 explain this kind of lining.†

Simple cast-iron props may be used instead of timber for working places where they can be withdrawn. They are rather heavy, but they will serve over and over again. At some collieries a

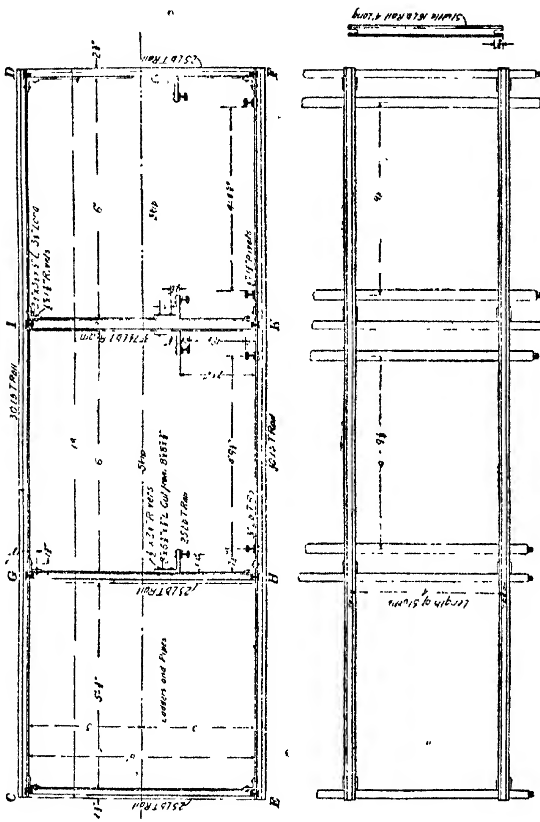
* "Der Schacht 'Kaiser Wilhelm II.' bei Clausthal," *Zeitschr. f. B.-H. u. S.-Wesen*, vol. xliii, Berlin, 1895, Plate XVII.

† Drake, "The Use of Steel in Lining Mine Shafts," *Mines and Minerals*, vol. xxiii., 1902, p. 128.



Figs. 130 and 131.—Circular shaft lined with steel, Clausthal; plan and elevation. Dimensions in metres and millimetres.

large number of these props, from 3 ft. 6 in. to 5 ft. 6 in. long, are employed, and they appear to give satisfaction. Cast iron



FIGS. 132 and 133.—Plan and side elevation of steel frames used for lining the shaft of a large iron mine, Michigan.

props are not suitable for resisting cross pressure, and they are liable to break occasionally when they happen to fall.

A common kind of prop is made of I iron or steel, either cut off square, or with the web cut out for a few inches and the two

flanges turned over so as to make ends with a larger bearing

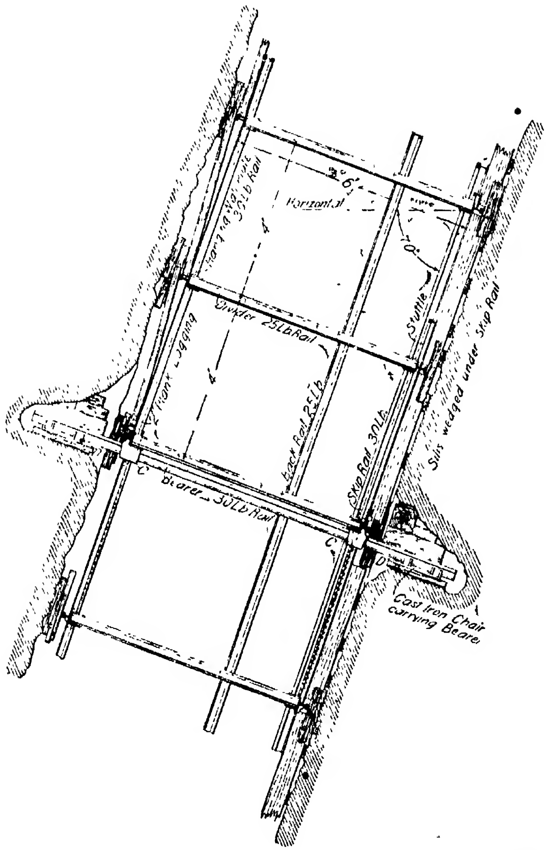


FIG. 134.—End elevation showing four successive frames in an inclined shaft, and also one of the 'bearers'

surface (fig. 135). The holes *a a* enable the props to be withdrawn by a hook.

(4) Special Methods of Support.

We now come to the special methods of support used in the case of soft, loose, watery or running ground. They are: (*a*) Spilling, spiling, or forepoling; (*b*) sinking drums or sinking linings, (*c*) coffering; (*d*) tubbing; (*e*) pneumatic pressure; (*f*) freezing.

(*a*) If the ground is loose, so that the roof or sides, or both, will run in unless supported, the method of working called *spilling*, *spiling*, or *poling* is pursued. It consists in supporting the weak parts by boards or poles in advance of the last frame set up. The process may be described as pushing out a protecting shield in very narrow sections at a time. The poles or boards (*laths*) are driven forward by blows from a sledge, and the ground protected by them is then worked away with the pick; the removal of this ground enables the lath to be driven in further; the pick is now

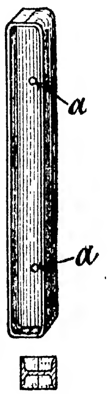


FIG. 135.—Steel prop.

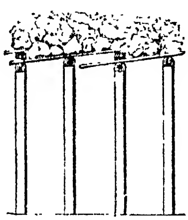


FIG. 136.—Driving through loose ground by spilling.

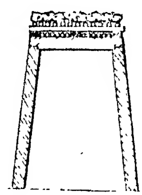


FIG. 137.—Section of frame and poles used in spilling.

once more called into requisition, and by successive small advances the shield of poles or boards is extended a distance of three or four feet. Fig. 136 shows one of the advance poles partly driven, with the front end resting on a set of timber; the pole behind it is in its final position. The section, fig. 137, explains that the lower set of poles, those which are in the course of being driven, have room enough to slide on the top of the cap, owing to the blocks placed upon it being slightly thicker than their diameter.

Spilling is likewise employed in the case of shafts. Strong balks of timber are fixed at the surface or in solid ground in the

shaft, and the first frame is supported upon these 'bearers'; the next frame is hung from the first, the third from the second, and so on until the loose ground is passed.

Planks (*laths*) are driven down around the outside of each frame, so as to form a hollow pyramidal shield, which keeps the loose outside earth from falling in while excavation is proceeding. In due time depth enough is gained to put in another frame; this serves to stay the lathes driven from the frame above, and also as a starting-point for a new set of laths for continuing the process of excavation.

(*b*) Sinking drums or sinking linings are hollow cylinders of brickwork or cast iron employed in sinking through quicksands; they gradually descend from their own weight or are forced down by hydraulic presses. The descent is aided by excavating in the bottom either by hand or by machinery.

(*c*) The method known as 'coffering' consists in lining the shaft with a wall, made of brick and cement or brick and hydraulic lime, and in backing this up with puddled clay. It is specially used for keeping back surface water.

(*d*) By 'tubbing' is meant a watertight lining to a shaft; it is put in with the object of preventing the influx of water from the surrounding strata, and of so saving the expense of pumping it out day after day and year after year. It may be made of wood or of cast iron, and the latter is the commoner material. The lining then consists of a series of rings, each ring being usually made up of several separate segments.

As a rule the cylinder of cast-iron plates is built up within a temporary timber lining, which is carried down until it reaches some solid and impervious stratum, below the water-bearing measures, fit to serve as a foundation. When such a foundation has been found, the sinking is continued for a few feet, and a bed is cut very carefully, and trimmed perfectly even and horizontal, so as to receive a foundation ring called a 'crib' or 'curb.' The curb is a hollow ring of cast iron made in segments about 4 ft. long. Strips of deal about half an inch thick are placed between every joint, and the segments are brought tightly together by wedging up the space between the outside of the curb and the rock. The joints are then rendered perfectly stanch by driving in wedges into the deal strips. A second curb is laid upon the first, with intervening strips of deal, and the wedging process repeated; sometimes a third curb comes upon the second. The top curb is the foundation for tubbing proper, which is built up segment after segment. The segments are usually 1 to 3 ft. high and 4 ft. long; their thickness depends upon the pressure of water they have to withstand, and varies from ½ to 3½ in. They are smooth inside,

but are strengthened with flanges and ribs on the side turned towards the ground.

The segments are kept in place by wedging them against the sides of the pit, and filling up the interspace with earth or concrete; thorough stanchness is secured by interposing a half-inch strip of deal or pitch pine at every joint, and finally driving in wedges when all the tubbing is fixed. Water coming in from the surrounding strata is allowed to escape through the central hole of each segment. A cast iron lining cylinder (figs. 139 and 140) is thus built up inside the shaft until an impervious stratum above the waterbearing ground is reached; another wedging crib then completes the tubbing. The joints are wedged up as tightly as

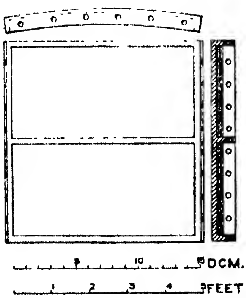
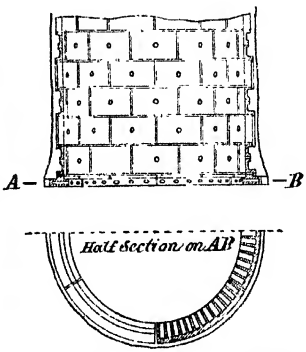


FIG. 138.—Cast-iron Tubbing Plate.



FIGS. 139 and 140.—Cast-iron Tubbing. Wedging Curb.

possible, and finally plugs are driven into the central holes of the segments. If the work has been properly performed, the linings will be watertight.

In France and Belgium the flanges are usually inside and the segments are joined by bolts. Sheet lead about ⅛-in. thick is interposed, and by screwing up the nuts tightly the joints are made quite tight.

When shafts are sunk by boring machinery, the cast-iron lining usually consists of a series of complete rings of cast iron, with internal flanges, which are bolted together. In the Kind-Chaudron process the huge hollow cast-iron cylinder constructed in this manner, and gradually lowered into the shaft full of water, is closed at the bottom, and it is provided with a 'moss-box,' a special

arrangement for making a stanch joint when the foot of the lining comes to rest upon a small ledge cut out on purpose by the boring tools. As soon as the descent has been safely accomplished, concrete is lowered into the interspace between the measures and the cast-iron rings, and this adds to the security of the lining.

The moss-box, the special feature of Chaudron's process, is not a *sine qua non*, and it has been successfully dispensed with in some sinkings in Northern France. The stanchness of the joint between the bottom of the column of tubbing and the surrounding strata is secured by very careful concreting.

(*e*) *Compressed Air Method.*—Sinking by compressed air was successfully introduced in France by M. Triger about half a century ago. The shaft lining is a cylinder of cast iron, lengthened by adding ring after ring at the surface, which sinks down gradually from its own weight as the earth in the bottom is worked away. In order to prevent the water in the surrounding beds from coming in, air under pressure is led into a chamber at the bottom of the cylinder, which is shut off by a horizontal partition or diaphragm. Above this working chamber there is an 'air lock' for preventing the working chamber from communicating directly with the atmosphere.

There are two great disadvantages coupled with this method :—

(1) The impossibility of going to a depth much exceeding 100 feet, because, speaking generally, a pressure of 45 lbs. per square inch, or three atmospheres above the normal pressure of the atmosphere, is about as much as men can stand.

(2) The fact that the health of the men has been found to suffer.

(*f*) *Freezing Method.*—Though Nature had long ago taught the Siberian prospector that he could stop the inflow from porous waterlogged gravel into his shaft by allowing frost to convert the strata into a hard impervious icy conglomerate, it was not until 1884 that Poetsch ventured to apply artificial cold for the same purpose.

Poetsch's process consists in causing a very cold liquid to circulate in pipes through the ground, and so freeze it into a solid mass, in which an excavation can be made without timber or other supports, and without any pumping. While the ground is still frozen, a cast-iron lining is put in, and it is so constructed that it will keep out the water, when the strata have thawed after the removal of the cold-producing appliances.

CHAPTER VI.

EXPLOITATION.

The term 'exploitation' may be conveniently adopted to denote the method of working, or, to speak more precisely, the method of arranging the working places in order to remove the mineral deposit in the most advantageous manner.

There are two principal methods of attacking and removing a mineral deposit, according as the work is carried on in places open to the sky, or in chambers and passages under a cover of rock or earth; and as gold-bearing gravel and phosphates are occasionally dredged up, and as liquid, gaseous, or soluble minerals are obtained by wells or boreholes, we have two further methods which are sometimes of much importance. Lastly, whilst the true 'getting' is carried on in workings open to the sky, it is sometimes combined with underground transport and hoisting.

The complete classification is, therefore, as follows:—

(1) Subaerial or open workings.
(2) Subaqueous workings.
(3) Wells and boreholes.
(4) Mixed open and underground work
(5) Subterranean or underground workings.

(1) Open Workings.

Some minerals are always obtained in this way; others are worked 'open-cast' before underground mining begins; and it may happen that underground and surface work are both being carried on simultaneously in adjacent parts of the same mine. Among the minerals often worked open-cast are coal, brown coal, gems, and the ores of copper, gold, iron, lead and tin, to say nothing of all kinds of stone.

The advantages of open works are numerous:—

(*a*) Complete removal of the mineral without any loss in the form of pillars.

(*b*) No expense or trouble as regards ventilation, men always working in good air; no danger of explosions.

(*c*) No expense for lighting, unless work is carried on at night.

(*d*) Little or no expense for timbering.

(*e*) Possibility of laying out work in larger steps or 'stopes' than can be usually done in underground working places.

(*f*) Easier supervision.

On the other hand, there is usually the immense disadvantage of having to remove a great deal of waste rock covering the deposit, technically known as *overburden*, or rock lying at the side which would inevitably fall into the pit if deepened considerably. Work, too, may be stopped by bad weather, such as heavy rain, snow or frost.

Generally the first process in an open working is the removal of the overburden, and the manner in which this is done depends upon the nature of the ground.

An example may be taken from Northamptonshire, where very large quantities of iron ore are obtained from beds of Jurassic age. The actual bed of ore at Cranford in Northamptonshire is 8 to 12 ft. thick, and the amount of overburden taken off is sometimes as much as 20 ft.; when this thickness is exceeded the ore can no longer be worked with profit.

The soil, or 'meat earth,' which is from 8 in. to 2 ft. deep, is put aside carefully, for it has to be restored to make the surface good and available for tillage. The remainder of the overburden is cut away in one or more steps or 'stopes,' for convenience and safety of the workmen, the base of any step being usually about equal to its height. The accompanying figure (141) represents a pit near Kettering in Northamptonshire where 15 ft. of overburden are removed from a 12-ft. bed of ironstone. The soil having been cleared off with a shovel, the men undercut the first stratum with a double pointed pick at *a* and then drive down a crowbar at *b* and another at a little distance from it. By working the bars backwards and forwards they cause a big block to break off along the dotted line. This crumbles in its fall, is shovelled into barrows, wheeled across the planks, and tipped on to the bank. After the top has been cleared away for a few feet, the next bed is treated in the same way, and then the third, until the ironstone is reached, and laid quite bare. The ore can usually be easily broken with the pick and at once loaded into small waggons, holding about a ton each. Occasionally a shot is fired in order to loosen parts that are hard. The loading is done with an eight-pronged fork, so as to separate the fine ore which the smelters refuse to take. If there is much fine, the ore is sifted; one man

stands over a wheelbarrow holding a round sieve with a half-inch mesh, and another shovels the ore to him. The fine drops into the barrow and can be wheeled away, while the coarse is thrown into the waggons. The men working on the overburden are paid by the cubic yard, and those excavating ore are paid per ton of ore placed in the trucks.

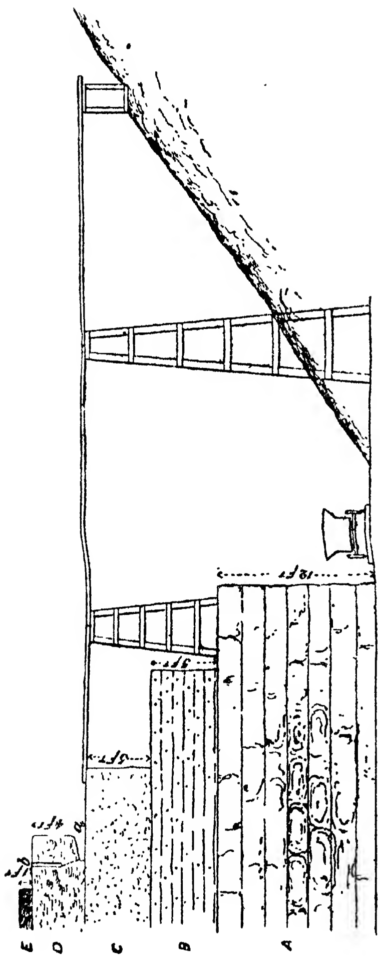


FIG. 141.—Open working for iron ore, Kettering in Northamptonshire.
A, iron ore; B, clay and sandy clay; C, sand; D, clay with fossil oysters; E, soil.

In hard rocks the steps may be made very much higher; at the Tharsis copper mine, Spain (fig. 142) each step or stope is about 33 ft. high. At the great Penrhyn slate quarry, near Bangor, in North Wales, the valuable slate and the valueless overburden are both taken away by a series of steps or terraces, on an average 60 ft. high by 30 ft. wide, as shown in fig. 143.

When the rock is firm enough to stand for a great height, it is sometimes found convenient to take it down in one vertical slice without making a series of steps.

Another method is that of firing a very large blast, which brings down thousands of tons of rock at a time. It is prepared by driving in a tunnel at right angles to the face of the quarry, and making one or more chambers, which are charged with gunpowder or some other explosive. The tunnel is then tamped up like a gigantic shothole, and the charge is fired by ordinary safety fuse or by electricity.

As already explained in Chapter IV., the term 'hydraulic mining' is applied to the method of open quarrying by the aid of a jet of water. The manner of obtaining the water under pressure

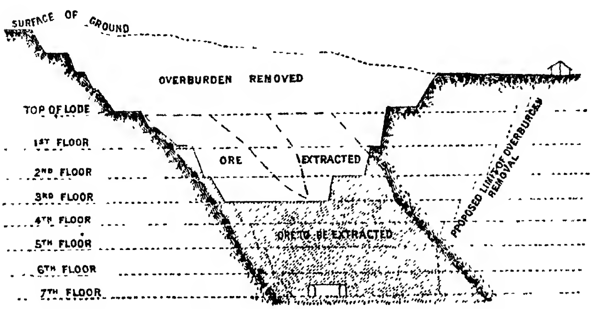


FIG. 142.—Open working for cupreous iron pyrites, Tharsis, Spain.*

and of applying it has already been explained. The stream of mud and stones coming away from the working face is led into 'sluices,' which are large wooden troughs paved with blocks of wood or with stone, or provided with false bottoms made of iron bars.

The big boulders rushing down the sluice are of service at first by breaking up gravel which may be much cemented together, but at the same time they naturally wear out the sides and the pavement. After they have been washed down the sluices for a certain distance, they are got rid of by a grating which shoots them into any convenient ravine or gully and lets the finer particles pass through.

* Courtney, "Mining and Treatment of Copper Ore at Tharsis, Spain," *Proc. Inst. C.E.*, vol. cxxv., 1896, p. 126.

Mercury is added several times a day at the head of the sluice, and the upper part, say the first 1000 ft., is cleaned up every

FIG. 143.—A small part of the Penrhyn Slate Quarry, North Wales, from a photograph by Mr G. J. Williams, H.M. Inspector of Mines.

two or three weeks. At the time of the cleaning up, the washing down of the gravel bank is stopped, or the current is diverted

into a parallel line of sluices. A small quantity of water is turned into the sluice to be cleaned up, the false bottom is taken out, and on the floor of the trough will be found the amalgam; it is scraped up with iron scoops, washed, squeezed through canvas or leather, and retorted. The spongy gold remaining behind in the retorts is then finally melted into bars. The mercury recovered by condensation is used over again.

It is not everywhere that the gravel beds occur in hilly countries where reservoirs can be constructed for supplying the necessary water under pressure and where convenient ravines exist into which the stone and earth can be shot after the extraction of the gold. The gold-bearing stratum is sometimes found under river flats without the two advantages named above, and in such cases a method known sometimes as 'centrifugal sluicing' and sometimes as 'hydraulic sluicing' is applied with profit (fig. 144). It is merely a form of hydraulic mining in which the jet of water is obtained by steam pumps, and in which the mud, sand and gravel are lifted by centrifugal pumps into gold-saving troughs (*sluices*) carried on trestles above the surface, and are finally discharged, after the extraction of the gold, into a pit or part of a pit already worked. An important feature of this so-called 'centrifugal sluicing' consists in the easy removal of the plant, which is placed upon a big barge or pontoon of very light draught; this rests upon the ground while work is proceeding, but can be floated from place to place as required, until all the best parts of the river flat have been attacked and exhausted.

(2) Subaqueous Workings.

In Chapter IV. mention was made of the dredges of various types which are employed for the purpose of extracting gold-bearing sand and gravel from the beds of rivers. Gold is not the only mineral worked in this fashion; in South Carolina phosphate of lime is dredged up from river bottoms, and in Prince Edward's Island a shell-marl obtained in the same manner is sold as a fertiliser. Lastly, on the coast of Germany, between Dantzig and Memel, two forms of subaqueous work have been applied to the getting of amber. The mineral has been obtained by divers and also by the use of bucket dredges.

(3) Wells and Boreholes.

Liquid, gaseous and soluble minerals are sometimes obtained in this fashion. The principal minerals are:—Carbonic acid,

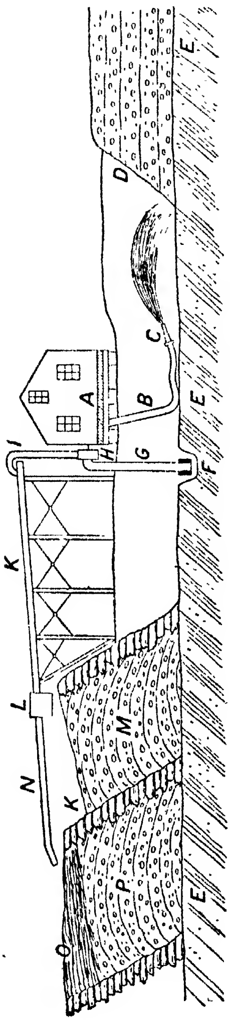


FIG. 144.—Diagram explaining 'Centrifugal Sluicing'.*

A is a barge or pontoon carrying all the machinery; B, a pipe coming from a centrifugal pump which delivers a jet of water through a nozzle C against the gravel bank, D; the gravel is resting upon the bed rock, E E: the stream of stones, sand and mud runs down into a well F, and is drawn up through a suction pipe G, by means of the centrifugal pump H, and is delivered through the pipe I into the run of sluices K with gold-saving appliances; L is a settling tank which allows the large stones to be discharged separately into M; the continuation of the launder N delivers the fine loam O on to a bed P of coarse gravel similar to M, and thus reproduces agricultural land.

natural inflammable gas, petroleum, and salt.

Underground supplies of carbonic acid are tapped by boreholes, and the 'getting' consists simply in piping off the gas from the top.

Precisely the same remarks apply to the case of the natural gas used for fuel in Pennsylvania and elsewhere, the occurrence of which has already been described.

The mineral petroleum is obtained either from wells or boreholes. In the United States, Russia, and elsewhere, boreholes are sunk by one of the processes described in Chapter III., and yield oil, which will rise either to the surface or part way to the surface. In this latter case it has to be drawn up by pumps or by huge bailers. In order to increase the

* *Australian Mining Standard*, Special Edition, 1st June 1899, Melbourne, Victoria, p. 163.

flow of oil from the surrounding rocks into the borehole, especially when a hole is beginning to fail, the oil-bearing stratum may be cracked, and broken up by a 'torpedo.' This is a powerful charge of some explosive contained in a tin cylinder, which is lowered into the hole to the required depth and then exploded. Nitroglycerine, dynamite or gunpowder may be employed, but of course the last is only used when its more powerful rivals

FIG. 145.—A small portion of the Balakhany oil-field, near Baku, Russia, with numerous derricks, each one over a borehole.

cannot be obtained. As much as a hundred quarts of nitro glycerine may be used for one blast, in which case the explosive is let down in separate cylinders, each containing twenty quarts. The explosion of the top cylinder fires the charges in the others.

The great bed of salt near Middlesborough is worked by making a borehole and putting in two tubes and a pump, so arranged that

the water from a superincumbent bed of sandstone travels down, dissolves the salt, and is then drawn up.

Natural sheets of saline water or brine exist in some districts, and can be tapped by wells or boreholes; indeed, salt was worked in this way long before the discovery of the rock salt. Some of the salt in Cheshire is derived from brine pumped up from inundated mines worked originally for rock salt, which are now full of water and cannot be entered.

(4) Open and Underground Works Combined.

As a typical instance of this method may be mentioned the so-called 'milling' process sometimes employed for working iron

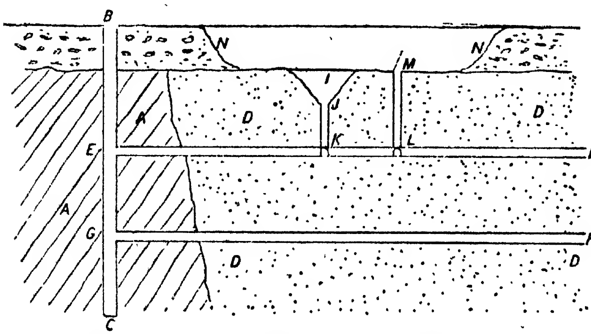


FIG. 146.—Extraction of iron ore by the 'milling' process.

A is barren rock in which the shaft B C is sunk; D is the ore; E F and G H are levels about 60 ft. apart; I is a crater or funnel-shaped pit in which work goes on; J K and L M are rises communicating with cross drivages driven out from the mine level E F; N is a thick layer of overburden lying upon the iron ore.

ore in Minnesota. While the overburden is being stripped off by a steam shovel, a shaft is sunk, and levels are driven off into the ore; drivages are made from these main levels at short intervals, and rises ('raises' or 'upraises,' U.S.) put up to the surface. Workmen then begin excavating around the top of each rise, into which they shoot down their ore; the bottom of the rise is fitted with a suitable door enabling waggons to be filled rapidly and easily. As working proceeds, each separate little pit assumes the form of a crater or funnel, and at some given moment the workings would have the form represented in fig. 146.

(5) Underground Workings.

The methods employed for extracting minerals underground are almost as varied as the minerals themselves.

The deposit must first be reached by a shaft, *i.e.* a vertical or steeply inclined pit, by an 'adit,' *i.e.* a nearly horizontal drainage tunnel, or by an 'incline,' *i.e.* a sloping tunnel. The choice between these three methods of attack must be governed by the contour of the country and by the general circumstances of the case.

Supposing the deposit to have been entered by one of these three methods, the problem before the miner is how to remove it to the best advantage.

Underground workings may be classified according to the nature of the deposit worked, that is to say, according as the deposit is a bed, a vein, or a mass; but such a classification is not entirely satisfactory, as it separates methods of working which are in reality identical. A steeply dipping seam is worked much in the same fashion as a vein; methods employed in working away thick veins often differ in no way from those found advisable in the case of many masses. On the whole, it is better to take some other criterion, and following Haton de la Goupillière, it will be seen that the removal of a mineral deposit by underground workings proceeds according to one of the three following great principles:—

(*a*) Chambers and permanent pillars, *i.e.* removal of the mineral incomplete, part left in the form of supporting pillars or pillars and floors.

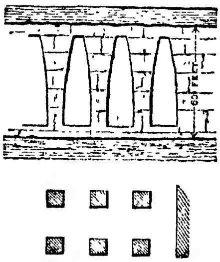
(*b*) Subsidence of roof or 'caving' method, *i.e.* removal of the mineral complete with subsidence of the roof.

(*c*) Filling up method, *i.e.* removal of the mineral complete, empty spaces completely filled with rubbish.

(*a*) *Chambers and Permanent Pillars.*—This system is frequently adopted with minerals of no great intrinsic worth, when the value of the pillars left behind is less than the cost of putting in the artificial supports which would be necessary in order to remove the whole of the deposit with safety. It is likewise adopted in certain cases for the purpose of preventing damage to the surface by subsidence, or an inroad of the sea when the workings are submarine.

The method can be best understood by characteristic examples which show how certain beds of gypsum and salt, and many mineral veins, are being worked.

Figs. 147 and 148 represent in section and in plan the chambers and pillars of the underground workings for gypsum at Paris, which supply the stone from which the well known plaster is made. The principal bed is from 50 to 60 ft. in thickness. Pillars are left 10 ft. square at the base, and the *stalls* between them are 16 ft. wide. The workings are slightly arched, and are not carried up to the true roof, for the purpose of better maintaining the security of the chambers, because heavy damages



FIGS. 147 and 148.—Underground workings for gypsum, Paris.

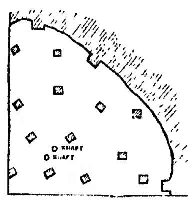


FIG. 149.—Plan of part of Marston Hall salt mine, Cheshire.

would have to be paid if they 'caved in' and rendered the surface useless. A similar layer of gypsum left for the floor prevents 'creep'—that is to say, a rising of the floor owing to the thrust of the pillars—and enables the underground roads to be kept in order with little expense.

The salt mines of Cheshire are an excellent example of pillar and chamber working. The bed is 84 ft. thick, but only the bottom part, 15 to 18 ft. thick, is mined. Pillars 10 yards square are left promiscuously about 25 yards apart, or closer if thought desirable in any special places. Fig. 149 represents part of Marston Hall mine near Northwich. The bed is almost horizontal, and is reached by two perpendicular shafts; wide stalls are then driven out on all sides. The workings are advanced by making an excavation in the upper part called the 'roofing' (*a*, fig. 150); and the lower two-thirds of the thickness worked are got by blasting

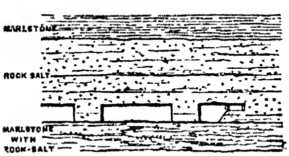


FIG. 150.—Vertical section, Marston Hall salt mine, Cheshire.

slanting holes. This is called the 'benching.' The roofing is made by 'holing' or under-cutting by hand, or better, by a circular saw driven by compressed air; when once undercut, it is easy to bring down the salt by horizontal holes bored with a jumper and charged with gunpowder.

We now come to the case of many mineral veins. The first attack is often made by an exploratory pit sunk along the dip for 20 or 30 fathoms, and if the indications found in driving out levels warrant further prosecution of the mine, a perpendicular working shaft is put down to intersect the lode at a depth of 100 fathoms or more from the surface. Cross-cuts are then driven out at intervals of 10, 15, or 20 fathoms to reach the lode as shown in fig. 151, which represents a vertical section at right angles to the line of strike. Sometimes the main shafts are carried down all the way along the dip of the vein, though perpendicular shafts have the advantage of being better suited for quick winding and cheap pumping, to say nothing of the rapid ascent and descent of the miners in cages.

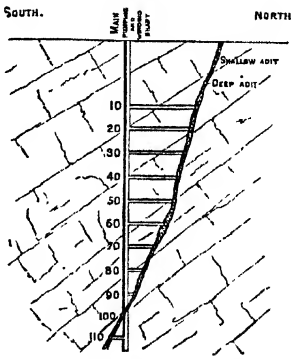


FIG. 151.—Cross section showing the common method of working a mineral vein.

Whatever kind of shaft is adopted, levels are driven out along the strike of the lode, as shown in the longitudinal section (fig. 152), in the hope of meeting with valuable ore-bodies such as are represented by the stippled portions of the figure. For the purposes of ventilation, and still furthur exploring the ground and working it, intermediate shafts, called 'winzes' (Cornwall) are sunk in the lode from one level to the other. In some cases the communicating passage is excavated upwards, or, in other words, the 'miner puts up a rise.' When communication is complete, there is no difference between a rise * and a winze.

On looking at the longitudinal section (fig. 152), which may be regarded as representing a common state of things, it will at once be remarked that only certain parts of a vein are valuable. When dealing with a bed or seam, we constantly find that the whole area covered by it can be worked away profitably. With

* *Raise* or *upraise*, U.S.A.

a lode this is an exception, and therefore the problem of exploitation is not the same in the two cases. The vein miner has to remove *portions* of a sheet-like deposit usually dipping at a high angle, and the bed miner has to excavate the *whole* of a sheet-like deposit lying frequently horizontal; but in any case, until the vein has been explored, it is impossible to predict how much of it can be removed with profit.

The poor parts shown in fig. 152, 'arches of ground' as they are called, are often frequent enough and large enough to provide an ample supply of buttresses for preventing the collapse of the sides, and the method of working is one of irregular pillars and irregular cavities.

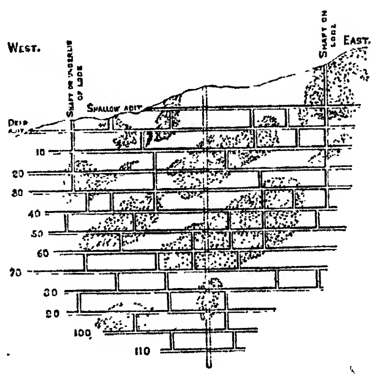


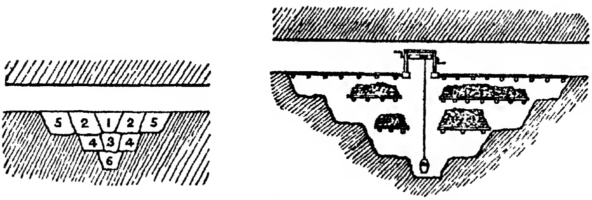
Fig. 152.—Longitudinal section showing the common method of working a mineral vein. The stippling represents the valuable parts of the vein which have been worked away.

The two sets of passages, *i.e.* levels and winzes, cut out the vein into a series of blocks, making the longitudinal *section* of the workings more or less closely resemble the *plan* of a mine on the post and stall system. There is, however, less regularity in the blocks, because the vein miner tries to locate his winzes as far as possible in profitable parts of the lode, and may often have to drive a long distance through valueless ground before arriving at desirable points for sinking to the level below.

We now come to the working away of the blocks; there are two typical methods, working downwards and working upwards. The former is called 'underhand stoping,' the latter 'overhand stoping.' The word 'stope,' which has no connection whatever

with the Scotch 'stoop,' is equivalent to 'step,' and the term 'stoping' means working away any deposit in a series of steps. Underhand or 'bottom stopes' are workings arranged like the steps of a staircase seen from above, whilst overhand or 'back stopes' are like similar steps seen from underneath. Both methods have their advantages and disadvantages, and both are largely used.

Underhand stoping is the older method. In the old days the



Figs. 153 and 154.—Underhand stopes.

miner began in the floor of the level (fig. 153) and sank down a few feet, removing the part 1; he followed with 2, 3, 4, etc., until the excavation finally presented the appearance show in fig. 154. Any valueless rock or mineral was deposited upon platforms of timber (*stulls*), and the ore was drawn up into the level by a windlass. One great disadvantage of this method was the cost of winding up the ore and water by hand labour.

A more economical method of working by underhand stopes consists in starting from the two upper ends of a winze separating two blocks, and the lode is removed in a succession of steps, the workings assuming the appearance exhibited in fig. 155. The steps are generally made steep, so that the ore may readily roll down into the winze, and so that the boreholes may do better execution; but these steep stopes are dangerous if a man happens to slip and fall. The huge open chasms left by the removal of a wide lode in this way are also a danger, for there is always a risk of falls of rock, and from places which cannot easily be examined.

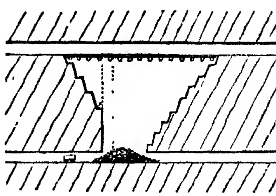


Fig. 155.—Underhand stopes, starting from a winze.

Overhand stoping is precisely the reverse of that which has been described; the work is commenced from a rise (fig. 156, A), or better, from two ends of a winze (fig. 156, B). As soon as the men have excavated a sufficient height of the level, they put in strong pieces of timber from wall to wall (*stemples, stull-pieces*), cover these cross-pieces with boards or poles, and throw down the rubbish upon the platform (*stull, bunning*) thus formed.

As they work upwards it may happen that there is not enough rubbish to fill the excavation entirely, and in this case they stand upon temporary stages or platforms (fig. 157).

The advantages of overhand stoping are these:—The miner is assisted by gravity in his work, no ore or rock has to be drawn up by hand labour, and less timber is required. On the other hand, he is always menaced by falls of the roof of his working-place;

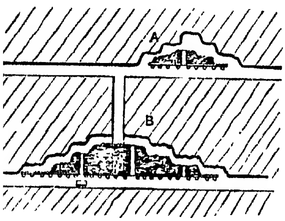


FIG. 156.—Overhand stopes.

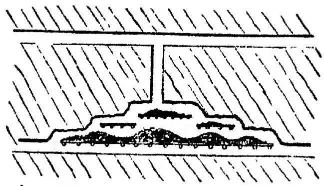


FIG. 157.—Overhand stopes with platforms.

but, as he is close by, he can constantly test the solidity of the roof and sides by sounding them with his sledge. A last disadvantage of overhand as compared with underhand stopes is the chance of valuable particles of ore being lost in the rubbish; however, this loss can be prevented by laying down planks or sheets of iron while the lode is being broken down.

When a seam is highly inclined, the system of working is often identical with that pursued in the case of a mineral vein. Thus in the Transvaal* the beds of gold-bearing conglomerate are cut up into blocks by horizontal levels and by small intermediate shafts following the dip. Each rectangle is about 120 ft. long and 120 ft. high, and it is worked away by the process of 'overhand stoping' (fig. 158).

* Moore, "The Witwatersrand Gold Field," *Trans. Inst. Eng. and Shipbuilders in Scotland*, vol. xxxviii., 1894, p. 49.

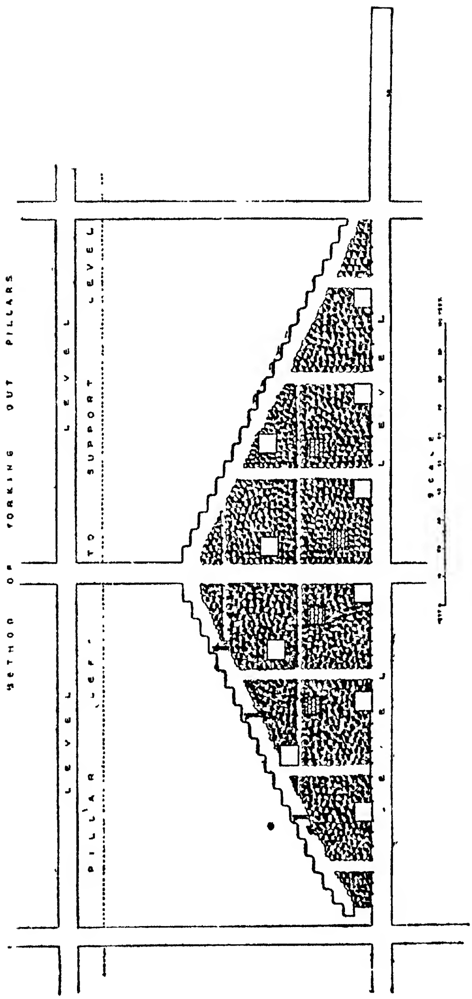


Fig. 158.—Overhand stopes, Johannesburg.

If a vein is very wide, and at the same time hard and strong, and if the supplies discovered far exceed the demands of the immediate future, the miner may sometimes adopt a pillar and chamber method, leaving the pillars as a reserve fund or legacy to his successors.

A system of this sort was devised for the huge deposit of pyrites at Rio Tinto, the arrangement that was proposed being illustrated by figs. 159, 160 and 161. The decomposition of the pyrites and the heating resulting from

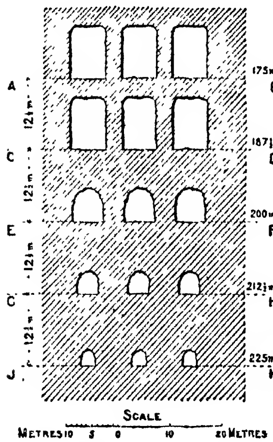


FIG. 159.—Pillar and chamber work, vertical section, Rio Tinto.

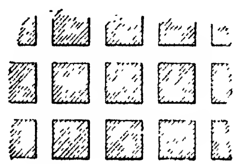


FIG. 160. —Plan of original pillars, Rio Tinto.

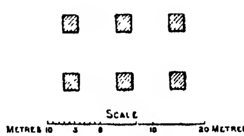


FIG. 161.—Plan of final pillars, Rio Tinto.

it, as the ore crushed and fell, led to constant dangers from fire, and the method of working never reached its ultimate stages.

A system of stoping and filling with waste rock was introduced in 1901. The lodes were divided into 15-metre wide vertical sections, and the stopes taken in horizontal slices across the lode. As the ore is removed the space is carefully filled, by hand, with gozzan or porphyry, the interstices being filled with fines, and the whole wetted to form

a compact mass. Levels and passes are protected through the filling. Alternate sections are stoped first, and later the intermediate pillars are extracted in the same way.

(*b*) *Subsidence of Roof, or 'Caving' Method.*—It is far more satisfactory from an economic point of view to leave as little of a deposit as possible; a larger output is obtained from a given working area if everything is removed, and it seems a pity, after a mineral deposit has been discovered, and after all the dead work of sinking shafts and driving levels has been accomplished, to allow any of the valuable material, the very object of the mining, to be left behind. It is by this method that much coal and much iron ore are obtained in this and other countries, and the Kimberley diamond mines afford another important illustration of the system.

This system is capable of many sub-divisions according to the nature and thickness of the deposit worked; these sub divisions are set forth in the table below:—

Deposits of medium thickness.	(α) Temporary pillars.
	(β) Long wall.
Thick deposits.	(γ) Network of tunnels and general 'caving.'
	(δ) Slices parallel to the dip.
	(ε) Slices parallel to the strike.

(α) *Temporary Pillars.*—In the early days of coal mining the workers endeavoured to remove as much as possible of the mineral in one operation; here and there they left some coal to support the roof, but the supporting blocks were comparatively small, and as they were surrounded by large open spaces, they could be fairly compared to the columns of a crypt. The names given to them—'pillar,' 'post,' and 'stoop' (a Scotch equivalent of 'staff')—were then thoroughly expressive. The workings were gradually extended, and eventually reached the boundaries of the property. Before finally abandoning the undertaking, the owner cut away what coal he could from the pillars, but he found that the small pillars, after having been subjected to heavy roof pressure for a few years, were generally greatly crushed and yielded little valuable coal; and a further disadvantage of this method was the troublesome 'creep' or rising of the floor, and the 'thrust' or sinking of the roof, which necessitated constant repairs of the roadways. The mine-owners set to work to remedy these evils by increasing the size of the supporting blocks and diminishing the width of the intervening spaces. The 'post and stall' system has thus

totally changed, and nowadays the amount of mineral obtained in the first stage is usually small compared with the main harvest from 'robbing' the pillars. The terms 'pillar,' 'post,' and 'stoop' are no longer proper similes, though commonly retained.

The plan of a mine worked by the pillar and stall system of the present day shows a number of rectangular blocks often 40 yards long by 30 yards wide, separated by drivages about 4 yards wide, as shown in fig. 162.

When the bed has been carved out into blocks in this way, the work of removing the pillars commences. As a rule, the attack begins on the pillars situated near the boundary, so that whilst the first carving out proceeds towards the boundary, the removal goes on in the opposite direction—viz., towards the shaft. A place or drift *a b* is worked across the pillar for a width of 2 to 4 yards, and then, starting from the drift *a b*, the rectangle beyond it is removed by drivages called 'lifts,' sometimes two in number, sometimes three, as shown in figure, and marked 1, 2, and 3. It may be necessary in some cases to leave a little of the pillar, in order to keep out the fallen rubbish beyond and to prevent a too sudden fall of roof. According to circumstances, it may be a corner of a pillar that is left, or a narrow strip on one side. The working place is timbered during the removal of the mineral, and when all has been taken out, the timber is withdrawn and the roof allowed to fall in. While the lifts 1, 2, and 3 are being worked away, another place *c d* is being driven across the pillar, which is preparation for another set of lifts 4, 5, and 6; lastly, lifts 7, 8, and 9 are worked away, with the exception of occasional small corners or strips, the removal of the pillar is complete, and its place is taken by fallen rubbish.

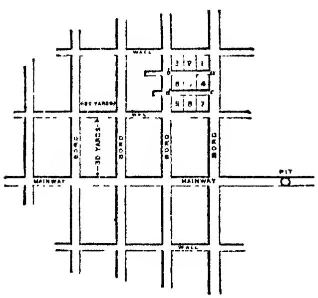


FIG. 162.—Pillar and stall workings.

(β) *Longwall Method.*—In the typical longwall method there is no preliminary carving out into blocks; the mineral is removed in one operation by the aid of long working faces or 'walls,' whence the name given to the system.

After the main roads have been driven out from the two

shafts, and a shaft pillar left to protect them, the working faces may assume the general appearance shown in fig. 163. Here A B is a main road connecting the long working face C D with the shaft; the various parts of the face C D are served by the roads *a b*, *c d*, *e f*, etc., which lead into oblique roads and so into A B. When the roads *a b*, *c d*, *e f*, etc., become too long, a new oblique road is started and portions of the old roads are abandoned, as shown by the dotted lines. As work proceeds the face will take the positions shown by the

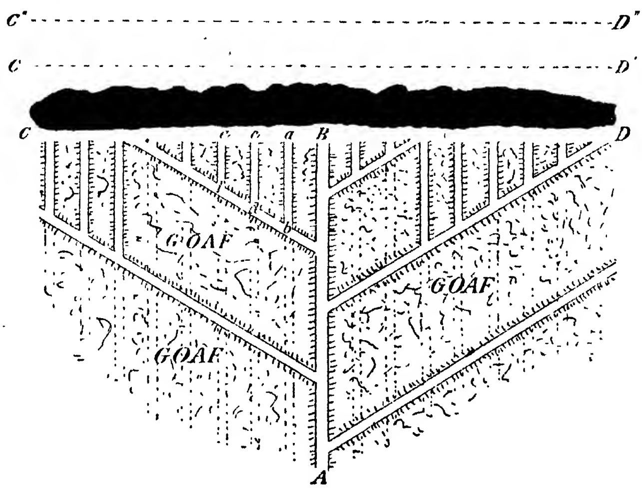


FIG. 163.—Diagram explaining the 'Longwall' system of working.

dotted lines C′D′, then C″D″ etc. The roof adjacent to the working face is duly timbered, and as the face is gradually worked away the hinder props are withdrawn and the roof allowed to fall; the roadways are maintained by building up pack walls at the sides. A working face such as C D may be half a mile in length or more. The advantages of this system are numerous—viz., simplicity, easier ventilation, economy—for the weight upon the face relieves the labour of getting, and more large coal is obtained. A decided disadvantage is that between the working face and the shaft there is the goaf, which may be

dangerous either as a holder of firedamp or as a source of underground fires; these sometimes arise spontaneously in a little coal left behind, and may cut off the retreat of the men to the shaft. Lastly, the expense of keeping up the roads in the exhausted area is often considerable.

Occasionally, instead of beginning near the shaft and making the working faces recede from it, the mine-owner waits before attacking the coal until he has driven out to his boundary. He then arranges his working faces so that they are continually approaching the shaft, and thus leaves the dangerous goaf behind him. The roads are in the solid coal and where they are more easily kept up than in the goaf, and the men at all times have a safe access to the shaft.

(γ) *Thick Deposits, Network of Tunnels and General 'Caving.'*—This is a system of working which has been applied in the case of the thick beds of sulphur-bearing limestone in Sicily. The bed must be divided in imagination into a series of thick slices, horizontal if the dip of thick seam is great, parallel to the dip if the inclination is moderate. In each slice a series of drivings and cross drivings is made by which a large quantity of mineral is extracted. The intervening pillars are then cut away and weakened, and finally a few shots are fired so as to bring some of them down completely. This causes a general collapse. New tunnels are driven into the mass of broken up rock, of which large quantities can be recovered; but the process is often inadvisable, the friction generated by masses of rocks crushing against each other frequently produces heat enough to ignite the sulphur; and underground fires started in this manner have often lasted for years.

(δ) *Thick Deposits, Slices Parallel to the Dip.*—This method is occasionally adopted in thick seams if the dip is not considerable. It is very easily understood, if one supposes the big seam to be sub-divided into a series of two or more slices parallel to the dip, each of which is worked like a separate seam. Working the uppermost slice lets down the roof, and when the next slice comes to be worked, its roof is constituted by the fallen stuff already consolidated into a coherent mass by the superincumbent pressure. Where the thick seam is naturally sub-divided into several portions by marked partings of waste rock, the adoption of this method is facilitated.

(ε) *Thick Deposits, Horizontal Slices.*—In dealing with a mass or with a thick bed dipping at a high angle, the method of working by horizontal slices is common. The slices are removed in descending order.

A good example is afforded by De Beers diamond mine, where a mass of diamond-bearing rock occurs as a huge column, with an irregular oval section (fig. 9). It was worked for many years as an open quarry, but falls of the surrounding rocks ('reef') caused so much trouble, as the huge pit increased in depth, that underground mining had to be adopted.

The system consists in excavating chambers, and then letting rubbish from the open pit run in and fill them up. The details of this method will be plain from consulting the figures. The

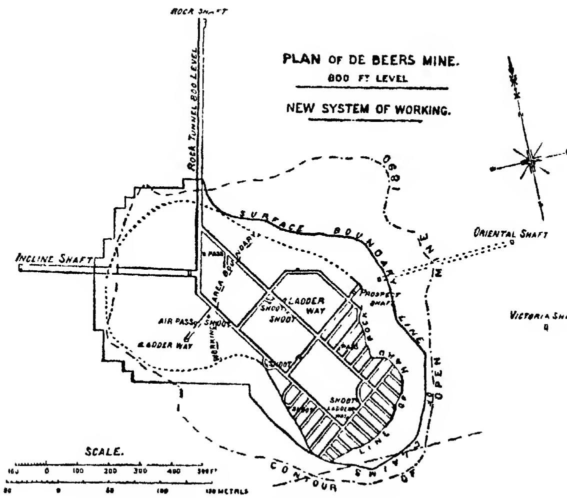


FIG. 164.—De Beers Diamond Mine. Plan at 800 ft. level.

deposit is reached by an inclined shaft sunk in the surrounding rocks, and main levels are driven at successive horizons which are from 90 to 120 ft. apart vertically. Fig. 164 shows the main drivages at the 800-ft. level; there are two principal drivages, parallel to each other and following the direction of the axis of the rough oval, and from them cross tunnels are put out at intervals of 36 ft., and extend to the limit of the 'blue,' or, when directed towards each other, till they meet. Another set of levels is driven at a depth of 30 ft. below the main tunnels, and a third

set at a further depth of 30 ft. The block of ground between two main horizons thus becomes divided up into a series of horizontal slices 30 ft. thick, each of which is cut up by a network of tunnels 36 ft. apart extending to the surrounding rocks. When this rock is reached, the tunnels are widened out till two adjacent working-places meet, as shown on the plan (fig. 164). The next process is to *rise*, or work upwards, until the 'blue' is traversed and the waste fallen rock above it is met with. This is allowed to run in and form a heap, upon which the workmen stand in order to blast down the remaining part of the slice of 'blue.' As this is taken away, the waste rock (reef) follows. Fig. 165 shows also that the workings in an upper slice are always further advanced than those in a lower one. Only the main levels are provided with regular tramways. The 'blue' got on the intermediate levels is thrown down shoots, and so finds its way to the main level, whence it can be hoisted to the surface.

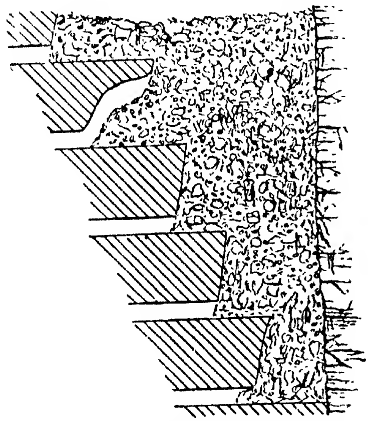


FIG. 165.—Vertical section of part of De Beers diamond mine.

(c) *Filling-up Methods.*

In this case the mineral is removed completely, and its place is taken by a filling of waste material. With thin seams or thin mineral veins it is frequently necessary to excavate a great deal of useless rock above or below the seam, or at the side of the vein, in order to have space enough for the body of the workman. Thus at Mansfeld, for instance, the workable part of the copper shale seam is only about 3 or 5 in. thick. From 15 to 20 in. of roof are blasted down in addition in order to make room, and all the waste so produced is packed or 'stowed' in the excavations and fills them up. The seam is removed on the longwall system (fig. 166).

Many seams have partings of waste, and many mineral veins have barren or poor parts which can be picked out, and all this

rubbish serves to fill the vacant spaces more or less completely; and in other cases it is considered desirable, for the purpose of safety and for preventing irregular subsidence, to pack the excavation entirely full of rubbish obtained from elsewhere.

The Van mine, Montgomeryshire, at one time the premier lead mine of the kingdom, affords an excellent example of a wide vein worked by the filling up method. The vein was often 40 ft. wide, and it would have been impossible to leave large open spaces with safety, because the hanging wall would most certainly have fallen away from a clay vein (*flucan*, B, fig. 167). The vein was divided

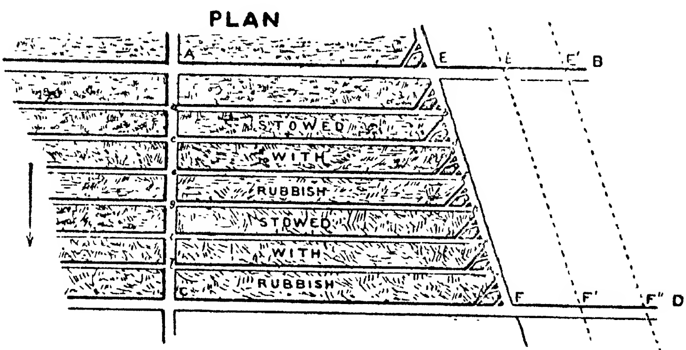


FIG. 166.—Plan of longwall workings, Mansfeld copper mines.

A B represents a main tunnel or level driven along the strike of the seam, which is dipping at an angle of about 5° or 6°; C D is the next tunnel below it; E F is the working face, a true 'long wall,' for it is from 600 to 800 yards in length; E' F' and E'' F'' represent future positions of the working face; *a*, *b*, *c*, *d*, *e*, *f* are subsidiary roads maintained in the 'goaf' or exhausted area which is stowed with rubbish.

into zones 90 ft. high, and each zone was removed by horizontal slices of about 6 ft. high. The zones were taken in descending order, the slices in ascending order, and as the ore was excavated, its place was almost immediately taken by waste, partly obtained from drivages in barren ground, and partly quarried specially at the surface and dropped down shoots.

Fig. 167 represents the state of things when about one half of a zone had been worked away. A and N are two crosscuts 90 ft. apart, driven through the soft *flucan* B and the poor or 'bastard lode' C, into the regular lode E. H H are main levels

along the strike of the lode. D represents a part of the vein whence the ore has been removed, the excavation being filled up with waste material. I is a shoot or 'pass' for throwing down the waste; K is a similar shoot for receiving the ore and conveying it into the level below.

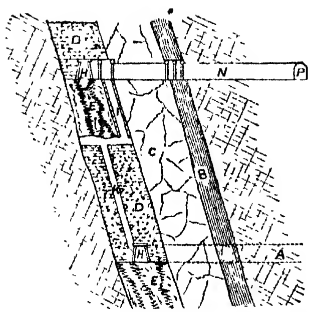


Fig. 167.—Working a wide lode by the filling-up method Van mine, Montgomeryshire.

Thick coal seams dipping at angles exceeding 45° or 50° are sometimes worked in a very similar manner.

Parts of one of the big veins of cupreous pyrites at Tharsis* have the excavating and filling processes carried out somewhat differently, but always with the same object in view, viz., complete removal of the mineral and avoidance of dangerously large open spaces. The vein is 52 ft. wide in places as shown by fig. 168. It is sub-divided into horizontal bands or zones 33 ft. thick, and each band or zone is removed crosswise, first by a vertical slice 16 ft. wide and then by parallel vertical slices 12 ft. wide. As the first slice is 'stoped' away from below upwards, two walls (fig. 168) are

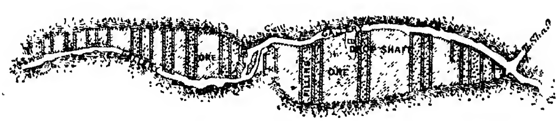


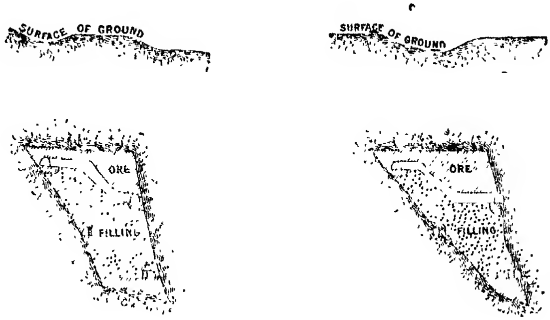
Fig. 168.—Plan showing method of extraction of ore, followed by complete filling up with waste material, Tharsis mine, Spain.

built up with rough stones and the interspace filled with rubbish; eventually the vertical slice of lode is replaced by waste held between two walls; when the adjoining slice is taken away, only one wall is required to keep up the waste.

Large excavations in the anthracite mines of Pennsylvania and the coal mines of Silesia are now being economically and

* Courtney, "Mining and Treatment of Copper Ore at Tharsis, Spain," *Proc. Inst. C.E.*, vol. cxxv., 1896, p. 126.

successfully packed by a water-flush system. Fine waste from the washeries, or granulated blast-furnace slag, is carried down



FIGS. 169 and 170. —Vertical section showing method of stoping and filling up, Tharsis mine, Spain.

into the mine by a current of water in pipes, and allowed to settle. The chambers are thus completely filled up and the intervening pillars can then be removed with safety.

CHAPTER VII.

HAULAGE.

The mineral broken down in the working place must be brought to the surface. In a typical mine the transport is performed in two operations: the mineral is first conveyed along a more or less horizontal road to a shaft, and is then lifted up this shaft into daylight. The former kind of transport is often called 'haulage,' and the latter 'hoisting' or 'winding'; but there is no strict line of demarcation between the two processes, unless the term 'winding' is restricted to raising mineral in a vertical pit. This, however, is a purely coal-miner's view of the question; and as the ore miner uses the word 'shaft' both for inclined as well as vertical pits, the practice of colliery engineers cannot be followed in a book upon general mining. It is convenient in dealing with haulage to include transport on the surface, because the plant and appliances are often identical with those employed below ground.

One form of transport, the railway, stands out as pre-eminently important, though not to the exclusion under certain conditions of other methods. The subject will therefore be considered under the following headings:—

(1) *Methods not Involving the Use of Rails.*
- Carriage by persons.
- Shoot and launders.
- Conveyors.
- Pipes.
- Sledges.
- Wheelbarrows.
- Pack animals.
- Carts.
- Boats.

(2) *Railways.*
- Plant.
- Power.

(3) *Aerial Ropeways.*

(4) *Loading and Unloading Ships.*

(1) Methods not Involving the Use of Rails.

Carriage by Persons.—The simplest and no doubt the oldest method of transport is carriage by persons. Where it is the custom of the country to carry goods of all kinds on the head or on the back, it is not unnatural to find this method of transport adopted for mineral. Thus, women are employed in India to carry coal in baskets from the working places to the nearest tramroad; boys carry sulphur rock in Sicily, men and boys carry slate in Germany and France, and transport of this kind may further be seen in Continental Italy, Spain, Mexico, China, and Japan, and even at home in the Forest of Dean. The work is not confined to horizontal roads, for the mineral is sometimes conveyed up steep steps or even ladders in this fashion.

Shoots (chutes, U.S.A.).—These are passages or troughs for conveying mineral downwards by the mere action of gravity; this is often the cheapest and easiest way of conveying mineral short distances from the working place to a proper roadway. When a mineral vein is being stoped away overhand, a space like a chimney is reserved in the rubbish by building a wall of stone or putting in a timber lining, and the mineral is dropped down this 'pass,' 'mill,' or 'chute' to the level below (fig. 167). If a proper door is provided at the bottom, the waggons can be loaded cheaply and expeditiously.

The use of shoots is not confined to underground workings; they are employed on the surface in hilly districts, and indeed it has sometimes been worth while sinking a shaft in a mountainous country for the sole purpose of dropping ore down it and so saving the expense of the difficult conveyance along precipitous paths. Fig. 171 * represents an ore shoot on a steep bank; it is simply a sloping wooden trough.

Conveyors.—The term conveyor is applied to a number of appliances, which, while tending to the same end, perform their work in very different ways.

The 'screw conveyor' is an Archimedean or a skeleton screw working in a trough and pushing along its contents. A second form is the trough conveyor, in which the mineral is scraped along by a series of discs attached to an endless rope or chain. Mineral is often conveyed by endless belts, and a recent form, the Robins Conveyor, has met with a large amount of success. As shown by figs. 172 and 173, it is an india-rubber belt running upon rollers. By suitably arranging the rollers or idler pulleys at the

* Brewer, "Texada Island," *Eng. and Min. Jour.*, vol. lxxii., 1901, p. 665.

sides, the belt is bent into the form of a trough—indeed, it becomes a travelling trough. The lower half of the belt runs upon flat rollers, as the curved shape is no longer required (see also fig. 76). The Kreis Conveyor is a trough, supported by springs, which has a reciprocating motion imparted to it by means of a crank.

Pipes.—The pipe is available where liquid or gaseous minerals have to be conveyed; but it is of more use on the surface than underground. Brine is taken long distances in wooden or iron pipes, and there are thousands of miles of pipes, especially in the

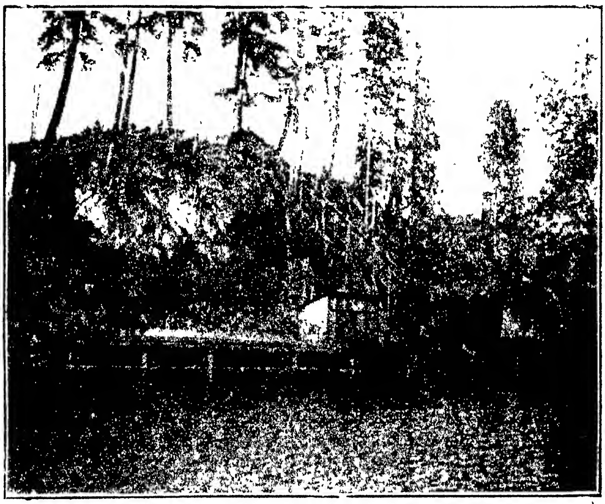


FIG. 171.—Ore shoot, Texada Island, B.C.

United States, for conveying petroleum and natural gas. The long petroleum pipe lines are divided into sections, and each section is provided with a pump which forces the liquid through the pipe which lies upon the undulating surface of the country.

Sledges.—Hand sledges, or sleds, enable heavy loads to be carried, but the road must slope downwards; they are little employed underground. Their use survives in mountainous districts for transport down sloping paths; their great disadvantage is the toil of carrying the sledge back uphill. Sledges

drawn by horses have been employed even in recent years in North Wales for the conveyance of manganese ore.

Fig. 172.—Robins Belt Conveyor, used also as a picking table, War Eagle mine, Rossland, B.C.

Fig. 173.—Robins Belt Conveyor, used also as a picking table, North Hill iron and zinc mine, Franklin, N.J.

Wheelbarrows.—Wheelbarrows are made of wood or steel, with a wooden or a steel wheel; they are tipped sideways, or over the

end. The wheelbarrow is often propelled along the natural floor of the working place or level; a proper road made of planks or sheet iron lessens the labour considerably.

Pack Animals.—Horses, mules, ponies, donkeys, or camels laden with sacks of mineral are a common sight in various parts of the world where cart roads have not yet been constructed.

Carts.—In the low passages only 18 in. high between the working faces and the main roads at the Mansfeld mines, tiny waggons, with four wheels running upon the natural floor, are

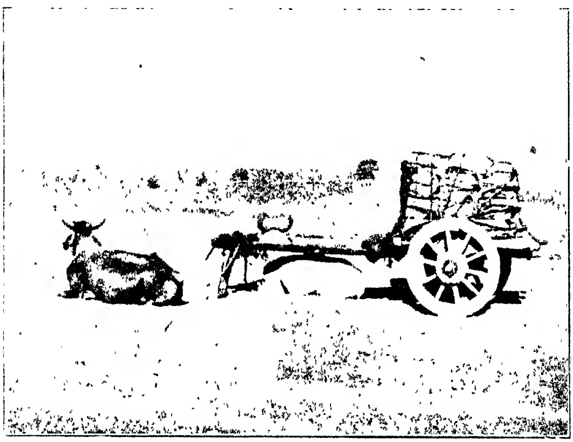


FIG 174.—Bullock cart conveying stone from a quarry, Karachi, India. The load is fastened on by ropes.

employed for the transport of the copper ore. They are drawn by boys.

Carts drawn by horses are used in some underground quarries.

Above ground the cart has been a common method of transport for all kinds of mineral from time immemorial; it is drawn by all sorts of draught animals.

Boats.—Conveyance by boats underground is very exceptional. In this country there is an adit level at the Tankerville and Bog mines in Shropshire, which is known as the 'boat level,' because lead ore was formerly carried in boats to its mouth, a distance in some places of $1\frac{3}{4}$ mile. This level now serves merely as a drainage tunnel.

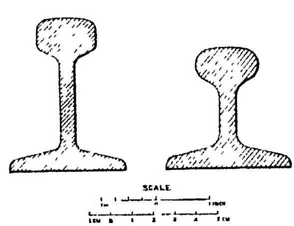
At the Dorothea mine, near Clausthal, in the Hartz, there is a level more than 400 yards below the surface, along which there was at one time a large amount of traffic by boats, each of which carried about five or six tons.

(2) Railways.

The points to be considered are: (*a*) the plant, including rails, waggons, points, turntables, etc.; and (*b*) the means of propulsion.

(*a*) *Plant.* - Various forms of rails are in use. The simplest is a bar of iron set on its edge, or a strip of flat iron nailed to the longitudinal sleepers. Rails of the former kind are made, for instance, of bars $\frac{7}{8}$ by $2\frac{1}{2}$ in., or $\frac{3}{4}$ by $2\frac{3}{4}$ in., fixed by wooden wedges in slits cut in the sleepers. This rail has the disadvantage of wearing a groove in the flange of the wheel, but it is easily and quickly laid and readily bent into curves. Rails made of bars of round iron are used in some Welsh slate quarries.

The bridge rail was in favour at one time, either laid upon longitudinal or cross sleepers; but nowadays flanged T-headed rails made of steel are preferred. Care should be taken to have strong and well-laid lines, especially where there is likely to be much traffic. In this, as in many other departments of mining, it is very bad economy to cut down the expenses too much. What is saved on the first cost by putting in light rails will be spent over and over again in repairs, to say nothing of the loss of time and money caused by delays in the traffic.



FIGS. 175 and 176.—Sections of steel rails.

The gauge varies from 14 in. to 3 ft. or more; 20 in. to 22 in. is a common gauge in vein mining. The weight of the rails for such roads is from 10 to 30 lbs. per yard. Figs. 175 and 176 show the sections adopted respectively by Legrand of Mons, and Howard of Bedford, for rails weighing 18 lbs. per yard. The rails may be simply spiked to wooden sleepers, or they may be laid in chairs. In important roads fishplates should be used.

Steel sleepers have proved to be very convenient and efficient, and in this country they are often cheaper in the end than wood. Among their advantages are exact uniformity of gauge, easy and

rapid laying, fewer repairs. They are usually made of rolled steel, and the rails are fixed either by clips, or by clips and keys.

Points and crossings must be provided. The points may be like those of an ordinary railway, with tongues moved by levers. Another plan is to leave gaps between the rails where the lines diverge or cross, and interpose plates of cast iron upon which the flanges of the wheels run without any difficulty. This arrangement is suitable for cases where a man is pushing the waggon, for he can turn it on to whichever road he chooses, but it will not answer in the case of haulage by engine power. Each plate has a rim or edge on the outer side, which prevents the wheels from running off.

Flat plates, or 'flat sheets,' as they are often called, are commonly used where there is a very sharp bend in the road, such as when a cross-cut joins a level almost, if not quite, at right angles. The plate is made of wrought iron or cast iron with ridges forming prolongations of the rails, as shown in fig. 177. The waggon leaves the metals and the flanges of the wheels run upon the plate; as its surface is perfectly smooth, the waggon is easily turned into the required direction, and the curved ridges guide the wheels into the track which they have to follow.

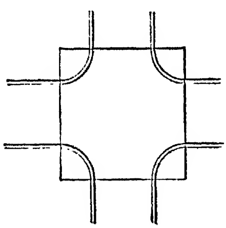


FIG. 177.—Flat plate.

The inclination of the road is not without importance, because there are usually waggons travelling in both directions: full ones going towards the shaft or other outlet from the mine, and empty ones returning to the working places. The inclination downwards towards the shaft assists the work, but if it is too great the return journey causes a useless expenditure of labour.

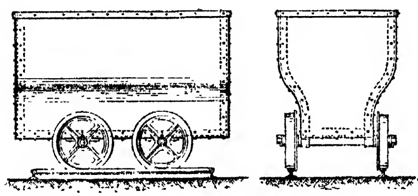
Inclinations varying from $\frac{1}{8}$ to $\frac{1}{4}$ in. per yard, or 1 in 288 to 1 in 144, are common.

The condition of the road between the metals deserves more attention than is usually bestowed upon it.

The waggons (*trams, tubs, hutches, bogies*) are made of wood, iron or steel. They consist of a body or box resting on a frame carried by four wheels. They vary greatly in shape and size according to the nature of the excavation and the kind of material transported. In some localities, where the conditions vary but slightly, waggons of standard shapes and sizes might be adopted with profit.

In some mines the mineral is loaded in the level into an iron bucket (*kibble*) standing upon a trolley, which is merely a small platform upon four wheels. This trolley is pushed (*trammed*) to the shaft; the full kibble is hooked on to the winding rope and drawn up, whilst an empty kibble is placed upon the trolley and trammed along the level to the spot where it is again loaded from a shoot or by a shovel.

Wheels for mine waggons generally have a single flange, and are made of ordinary cast iron, chilled cast iron, cast steel, or forged steel. Steel and chilled cast iron are the materials most in favour; both have advantages. The wheels made of chilled cast iron are rather heavier than those of steel, and are brittle; the flange, for instance, will break under a blow which will not damage a steel wheel; but a pair of chilled wheels will often outwear several pairs of steel wheels, if they happen to escape the hard raps to which mine waggons are liable



FIGS. 178 and 179.—Side elevation and end elevation of a common form of mine waggon.

Much difference of opinion and practice exists concerning the attachment of the wheels. Four systems are in vogue: axles fixed and wheels running loose upon them; wheels fixed to the axles, which run loose in pedestals attached to the frame or to the body of the waggon; thirdly, a combination of these two systems, viz., wheels running loose on the axles and axles running loose in the pedestals; fourthly, one wheel fast on the axle, and the other loose.

The following points should be considered in designing a mine waggon:—

Smallest weight compatible with strength.

Small height, if the waggon is to be filled with the shovel.

Protection of the wheels from injury.

Constant lubrication.

Adoption of a uniform type of waggon for the mine, or if possible for the district.

Material which causes the least expenditure for repairs.
Easy handling and easy replacement on the rails
A form which will not tend to produce dust.

In a few exceptional cases the mineral raised in the mine does not require a box or chest. This happens with slate, for the blocks are brought up on trucks to which they are made fast by chains.

(b) *Means of Propulsion.*—The power for moving mine waggons is obtained from one of the following sources:—

α Men, boys, women and girls.
β Horses, ponies, donkeys, and mules.
γ Gravity.
δ Mechanical power:
  Travelling engine.
  Stationary engine.

α Female labour underground is prohibited by law in the United Kingdom, and no doubt it is destined to disappear in most other countries. We need deal only with men and boys. Where the passages are high enough to take waggons standing 3 ft. above the ground, men are usually employed for drawing or pushing them. It is convenient to have waggons small enough to be handled by one man, and also to be put back on to the road by one man, if by chance they leave the rails.

The large waggons and loads at Festiniog require two men, for the load of rubbish commonly amounts to $1\frac{3}{4}$ or 2 tons. The waggon and load together may weigh as much as $2\frac{1}{2}$ tons.

β Traction by horses or ponies is cheaper than using human power, but it is not always practicable to employ it. There are many ore mines in which it would be impossible to lower a horse down a shaft; and even where the descent could take place, there would often be the further drawback, that as the work proceeds with comparative slowness, owing to the hardness of the rock, there would not be 'stuff' enough broken in a given time to keep a horse constantly employed at any particular level, whilst shifting it from one level to another would entail much difficulty.

On the other hand, at collieries with their larger output, animal power is greatly employed.

The horses are stabled below ground, and much care is taken in many instances to provide proper accommodation for them. The stables are paved with bricks or concrete, sloping towards a gutter; each horse has its stall, or a loose board is hung between every horse and its neighbour. Clean water is at hand for drinking.

γ In working stratified deposits, it is often necessary or convenient to lower a waggon down an inclined plane following the dip. Inclines for this purpose usually have two lines of rails, one for the descending and the other for the ascending waggon. A wire rope or a chain passes round a pulley or drum at the top, the axis of which may be horizontal or at right angles to the plane of the deposit. Each end of the rope can be hooked on to a waggon, and the weight of the full waggon going down suffices to raise the empty one. The speed is regulated by a break on the pulley or drum.

Another method of working inclines is to make the full waggon when it descends draw up a weight, running on a special line of rails, which is heavy enough to bring up the empty. In order to economise space, the line of rails for the weight may be made narrower than the one used for the waggon, and may be laid between the two main rails.

If the incline is steep, a carriage with a horizontal platform is provided. The mine waggon is pushed on to this travelling platform and ascends or descends in its ordinary position. Self-acting inclines above ground serve the miner in good stead where the country is hilly, and are often constructed on a very large scale.

δ Machinery is employed for haulage purposes either in the form of travelling engines or stationary engines.

Locomotives fired with coal have the great disadvantage of polluting the air by the products of combustion, consequently they are not available unless the ventilation is very good, nor unless there is an absence of inflammable gases and freedom from the risk of setting fire to the timbering or to the mineral itself. A small locomotive of two-horse power is used on an $18\frac{1}{2}$-in. track in the long adit of the Great Laxey lead and zinc mine in the Isle of Man; and at Rio Tinto in Spain a much larger engine plies in the adit on a line with a gauge of 3 ft. 6 in.

Locomotives driven by compressed air, carried in a large reservoir, improve the ventilation instead of injuring it, and entail no danger from fire; but, except in special cases, they cannot be worked so cheaply as engines fired with coal. Air locomotives are employed in several mines in the North of England, and in the United States (fig. 180).

An enormous amount of underground traffic is carried on by the power generated by a stationary prime mover placed above or below ground, and this practice is far more developed in collieries than in vein mining, where the quantities of mineral to be handled are as a rule very much smaller.

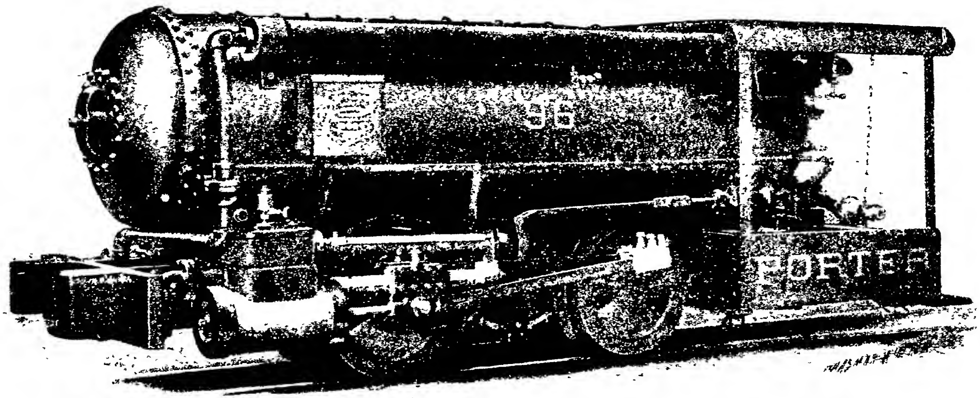


FIG. 180. —Compressed Air Mine Locomotive, built by H. K. Porter Co. for the Commonwealth Iron Co., Cleveland, Ohio.*

* Hirsch, "Compressed Air Haulage Systems," *Eng. Min. Jour.*, vol. lxxiii., 1902, p. 377.

The subject of transmission of power has already been sufficiently discussed in Chapter IV. and need not be dealt with here, save that it is necessary to point out that the conditions of the problem are not the same when power has to be applied to haulage as when it is required in a constantly changing working face. As the mineral has to be brought to the shaft, a steam engine and its boiler, if necessary, can be placed in the immediate vicinity of the pit bottom and the exhaust steam can be got rid of without interfering with the comfort of the men or injuring the condition of the workings. Proper rooms can be made for the engine and the boiler; coal can be brought down and the ashes removed without difficulty. Everything can be arranged in a permanent and substantial fashion, so that the steam power may be generated on the spot for haulage purposes below ground when it would not be practicable to employ it for breaking down the mineral. Again, when power has merely to be transmitted down a vertical shaft in order to work a drum near the bottom, endless ropes may be used, although they would be quite out of place if they had to be carried along narrow, low, and crooked levels.

Five systems of haulage by means of a stationary prime mover are in use:—

i. Single rope.
ii. Main and tail ropes.
iii. Endless rope.
iv. Endless chain.
v. Electric locomotive.

i. The single rope system is available with a road sufficiently inclined for the empty waggon to run down of itself, after the load has been brought up, and draw back the rope with it. One road will suffice, and the machinery required will be some kind of drum, around which the rope is coiled, and an engine for driving it.

The drum is usually placed horizontally; it is provided with a break, and there is a disengaging clutch by which it can be thrown in or out of gear with the engine. A pair of horizontal engines which have their cranks upon the drum shaft, or which drive it by means of a pinion and spur wheel, form the common method of applying the power.

The wire rope has one end fixed to the drum and the other is provided with a hook of some kind; this is attached to a link of the coupling chain of the truck and the load is drawn up. On reaching the top of the incline or engine-plane, the waggon is un-

hooked, and either pushed, or allowed to travel of itself under the action of gravity, to the pit bottom, where the onsetter runs it on to the cage in which it is raised to the surface.

An empty waggon is then hooked on and run on to the incline, and the engineman, with his break under proper control, disengages the drum by means of the clutch and lowers the load without using any steam. When worked in this way, the incline requires only one line of rails. A series of rollers have to be put in for the purpose of keeping the rope from trailing on the ground, and of thus preventing much unnecessary wear and friction.

The incline may be worked with two lines of rails, after the fashion of the self acting inclines; and this system has the advantage of being more economical, for the dead weight of the loaded waggon coming up is balanced by the weight of the empty one going down. It is not even necessary to have two lines all the way; provided there is a sufficient length of double line where the waggons meet, the incline can be worked with a length of single line at the top and a similar length of single line at the

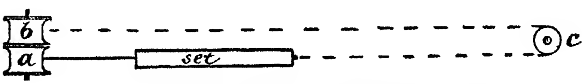


FIG. 181.--Diagram explaining main and tail rope haulage.

bottom. To prevent a waggon from running down in case of the rope or a coupling link breaking, a safety appliance, called a 'backstay,' may be attached to it. It is a sort of a fork which hangs behind the waggon, and just touches the ground; if the rope breaks, it digs itself into the road and prevents the waggon from going down.

ii. On the engine plane just described, the empty waggon goes back under the action of gravity; with very slightly inclined, flat, or undulating roads this is impossible. One method of overcoming this difficulty is to add a rope, called the 'tail rope,' which will draw the empties back; the rope which draws the full waggons is known as the 'main rope.'

In fig. 181 *a* is a drum upon which is coiled the strong main rope: *b* is another drum upon which is coiled the tail rope, passing round the pulley *c*. The waggons are coupled together and form the train or 'set,' which may in reality consist of as many as a hundred waggons. Suitable clutches enable either drum to be worked at pleasure by the engine, while the other is allowed to run loose upon the shaft. Each drum has a break, by means of which the

rope can be prevented from becoming too slack while uncoiling itself. When the drum a is made to revolve by the engine, the main rope is wound up, the drum b running loose, and the train or 'set' is drawn from c to a. Here the waggons are uncoupled and pushed to the shaft, or, better, the station at a is arranged so that there it is sufficiently high for the waggons to run down of themselves under the action of gravity. A new train of empties is then made up, the main and the tail ropes are attached to it, and the drum b set in motion so as to wind up the tail rope and draw the waggons into the terminus at c. It will be evident from a glance at the figure that the tail rope must be twice as long as the main rope. As the tail rope has simply a train of empties to haul out, it may be made smaller than the main rope, except in cases where the road has a downward inclination towards the shaft sufficient to cause the loaded train to run down of itself and draw the tail rope after it.

iii. A common method of underground haulage is by an endless rope passing round a pulley at each terminus, and generally travelling continuously in the same direction. The rope is kept in a state of tension by carrying it round a tightening sheave, which in some instances is one of the terminal pulleys. The tightening sheave or pulley is carried by a frame running up on wheels, and is constantly drawn back by a heavy weight. The necessary grip of the rope is obtained by coiling it several times round the driving drum, or round a driving pulley with grooves and a second grooved pulley close by; the rope wraps itself, for instance, upon three half circumferences of one pulley and two of the other. The speed of an endless rope is usually from two to three miles an hour, though instances may be cited of as low a speed as one mile an hour. The endless rope system admits of so many modifications that to attempt to enter into details would occupy too much time; it will suffice here to point out that two classes may be made according as the waggons are attached singly at intervals along the rope, or are made up into trains (*sets*), and each of these may be sub-divided according as the rope is placed above the waggons or below them.

Several modes of attachment are in use. If the gradient is all up hill a very simple clip is sufficient. The rope is made to rest in a fork on the waggon, and as it is bent out of line of pull when in motion, it is held tightly enough by friction to draw along the load. If the gradient varies, a fork is put on each end of the waggon, or a screw clip is employed; this resembles a pair of tongs, the jaws of which are brought together tightly by a screw worked by a handle, and hold the rope with a firm grip.

iv. The endless chain may be looked upon as a variety of the previous system, a chain being substituted for the rope.

v. Where there is no danger from sparks, the electric railway forms a useful solution of the problem. The current supplied by a dynamo at the surface is conveyed along a wire suspended from the roof of the level; and it passes down a trolley arm to a motor, well encased in a strong iron covering, which by the aid of gearing drives two wheels of the locomotive. The general appearance of an electric mine locomotive is shown in fig. 182.

(3) Aerial Ropeways.

There are several varieties of these ropeways, the characteristics of the two most important are.

(*a*) Endless rope, which is the supporting rope and hauling rope at the same time.

(*b*) Two supporting ropes, and an endless rope for hauling the load.

In the former system there is an endless rope, supported by pulleys on strong wooden or iron posts placed at suitable intervals, which is set in motion by any available source of power. Suspended from the rope are buckets in which the mineral is carried. The buckets may be detachable at pleasure, or they may be fixed. Hodgson's original ropeway has detachable buckets suspended by iron hangers to grooved blocks of wood resting upon the rope. The carrying block has a spindle with a small grooved pulley, which can be made to run upon a rail at each terminus and so let the rope move on without the load. The bucket is filled from a shoot or hopper while hanging on the rail at the loading terminus. A workman then pushes it along the rail until the carrying block is taken up by the rope, which is always in motion; the load now travels along suspended from the rope, the carriers being constructed so as to pass over the pulleys. On reaching the unloading terminus, the carrying block is again shunted on to a rail, and the bucket is tipped by lifting up the catch which had kept it from turning about pivots. The empty is now brought round to the point where the rope, after passing round a terminal pulley, is about to begin its journey back to the loading station. Here it is shunted on to the rope and travels along with it.

On steep inclines the saddle or carrying block is sure to slip, and it becomes desirable to fix the support of the hanger tightly to the rope. In many cases the ropeway needs no driving power; the full buckets in their descent draw up the empties.

The two-rope system is suitable for larger quantities. Two

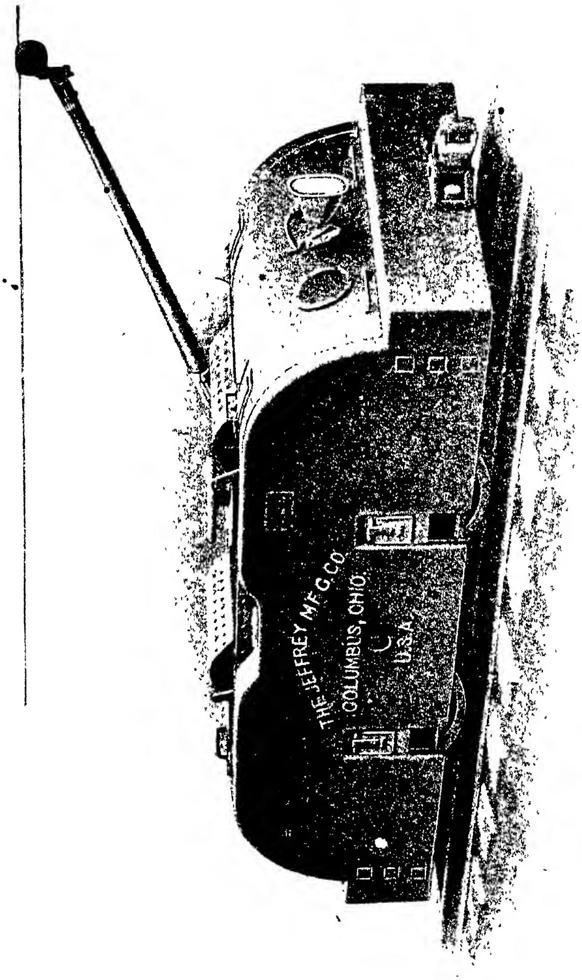


FIG. 182.—Electric Locomotive.

main ropes serve as aerial rails and act solely as supports, whilst an endless rope which is constantly travelling has the loads made fast to it at pleasure. Ropeways working upon this plan have been perfected of late years by Otto and by Bleichert in Germany,

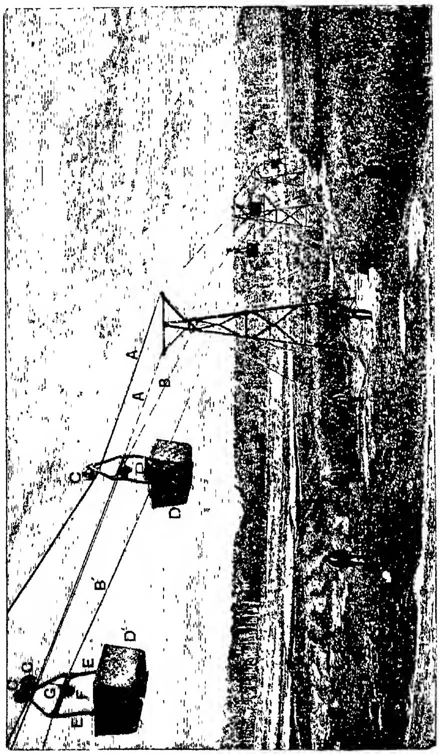


Fig. 183.—Aerial Ropeway, Otto system.

A A', Supporting ropes; B B', hauling rope; C C, grooved pulleys; D D', boxes; E E, hanger; F, clipping disc; G, projecting lever for tightening or loosening the clip.

where they are commoner than in this country. They are constructed for distances of from two to eight or even ten miles, with a carrying capacity of 600 to 800 tons per day of ten hours. The separate loads may vary from $\frac{1}{2}$ cwt. to 1 ton each.

The kind of cable used on the most recent lines erected on the

Otto system is that known as the 'locked coil wire rope.' It has the advantage of presenting a perfectly smooth surface, admirably adapted for the running of the grooved pulleys by which the load is suspended. The vessel in which the mineral is conveyed may be of any convenient shape, supported by pivots around which it can be easily tipped. Each receptacle is attached to a hanger suspended from a spindle placed midway between two grooved pulleys or wheels, which rest on the rope.

The posts or standards are constructed of wood or iron suitably stiffened by bracing and held in position by guy ropes or rods.

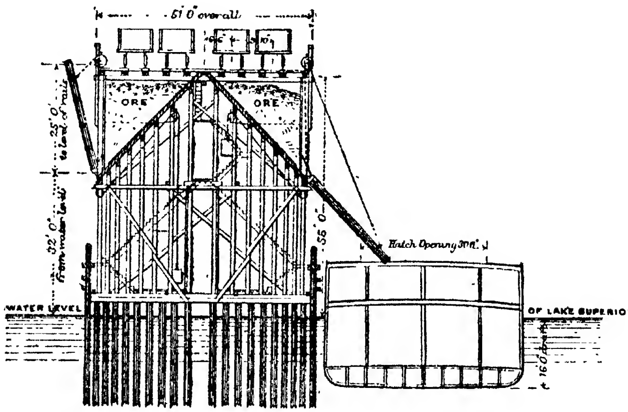


FIG. 184.—Cross section of wooden loading pier at Duluth, Minn., U.S.A.

The distance between the standards varies according to the nature of the country.

The hauling rope must be very flexible, and is made of fine steel wire with a hempen core. The mode of attachment of the load varies with the gradient of the line. If the gradient is less than 1 in 6, the amount of friction necessary for gripping the rope tightly can be obtained by bringing it between two flat iron discs and clamping them together with a screw. One of these discs is rigidly attached to the hanger, and the tightening screw of the other can be loosened automatically by providing a projecting lever, which comes in contact with a stop at the terminus.

If the gradient is between 1 in 6 and 1 in 3, the discs are made

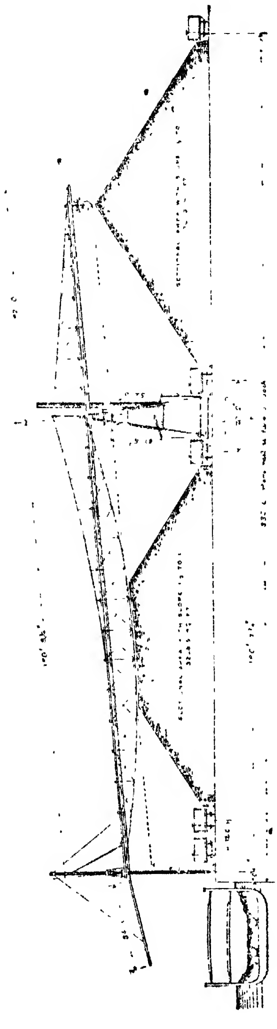


FIG. 133.—Brown conveyer for discharging iron ore ships.

with corrugated instead of smooth surfaces. When the gradient exceeds 1 in 3, another device has to be employed; projecting knobs are inserted into the rope at regular intervals, and on meeting with properly arranged stops upon the loads they cause them to travel along.

(4) Loading and Unloading Ships.

Where the mineral is being obtained in very large quantities, cheap methods of handling it require special attention; indeed, the answer to the question, "Can this mine be worked profitably?" will often depend upon the facilities for sending away and receiving its produce. It is well, therefore, for the elementary student to know something of the subject.

In no land has the matter been more carefully studied than in the United States, and an instructive example* is afforded by the transport of iron ore from the Mesabi Range mines in Minnesota to the blast furnaces of Pennsylvania. As already pointed out, the ore is often excavated by steam shovels which drop their contents into railway trucks. The trains are brought from the mines to

* Head, "Lake Superior Iron Ore Mines," *Proc. Inst. C.E.*, vol. cxxxvii., 1898-99, p. 72

the Port of Duluth, where a long pier runs out into Lake Superior; here the trucks are emptied into huge bins (fig. 184*) with hinged shoots.

An ore steamer is brought alongside the pier and a shoot is lowered into every alternate hatchway and the ore run down; the rate of loading varies from 1000 to 1600 tons per vessel per hour. The steamer then makes its way across the lake to the great lock at Sault St Marie, which lowers it to the level of Lake Huron, and it now proceeds to Cleveland or some other port in Lake Erie, where the Brown conveyors are largely used for the purpose of discharging cargoes. This conveyor is a long light bridge (fig. 185),* one end of which is brought directly over one of the hatchways of the ship. A big bucket (*skip*) holding 15 cwts. is lowered into the hold, filled by shovellers, and then drawn up and run along the bridge to be tipped, either into railway waggons or on to a stock pile. The lowering and raising of the skip and its run along the bridge are controlled by one man in a cabin. As each hatchway has its own conveyor, the work of discharging is rapid; 1000 tons can be unloaded in eight hours at the cost of $\frac{1}{4}$d. to $\frac{1}{2}$d. a ton.

* Head, *op. cit.*

CHAPTER VIII.

HOISTING.

By 'hoisting' or 'winding' is meant the operation of raising the mineral from the underground workings to the surface; but, as already explained, there is no strict line of demarcation between it and haulage when the work is done by an incline or 'slope.'

The appliances required are numerous, as will be evident from the following list:

(1) Motors, drums, pulley-frames, and pulleys; (2) rope, attachment of the rope; (3) receptacles for the mineral or waste rock; (4) keps, signals, and indicators; (5) safety apparatus.

(1) Motors, Drums, and Pulley-Frames.

As in other departments of mining, the motor employed may be worked by animal power, or by an engine driven by water, steam, compressed air, gas, petroleum, or electricity.

The simplest contrivance for winding is a pulley supported by some suitable frame above the shaft; a bucket is attached to the end of the rope hanging down the shaft, whilst the other end, passing over the pulley, is drawn by men or women; they simply walk away from the shaft and haul up the bucket. Large colliery shafts in India are sunk to a depth of 250 ft. by this primitive method of hoisting, which is likewise employed in Burmah in putting down oil wells.

Human power is usually applied by a windlass. This consists of a wooden cylinder, about 8 in. in diameter, provided with two iron handles and supported by two upright posts which are suitably stayed. A sliding bar, which can be drawn out either above or below the cylinder, serves as a catch for one of the handles when required.

In this country the ordinary windlass is used for shallow sinkings of 20, 30, or 40 yards in depth, such as are made in

commencing work at a mine, or in effecting communication between two levels; but in countries where labour is cheaper, the windlass may form the sole means of hoisting from depths of 100 and even 200 yards.

When a horse is employed in the place of men, the bucket, attached to a rope passing over a pulley, is sometimes drawn up by making the animal walk away from the shaft. The framework and pulley constitute what is called a *whipsiderry*.

Animal power is usually applied by means of a machine called a horse-whim. It consists of an upright axle, usually of timber, supported at the bottom by an iron pin or pivot, which works in a hole in a large stone forming a primitive foot-block. A horizontal beam, known as the driving beam, is attached to the axle, and above it comes a hollow wooden cylinder or drum, around which the rope is coiled, proper projecting horns or flanges being provided to prevent its slipping off.

The other end of the axle works in an iron socket, carried by a great horizontal beam, which is supported by two legs. The winding rope is coiled several times around the drum, and both ends, after passing over pulleys, hang down the shaft; when the horse walks round, one bucket is raised and the other lowered. As many as six or eight horses may be harnessed to a horse-whim for the purpose of working it.

When the waterwheel is used for hoisting, it is necessary to have means of reversing the motion, in order to raise or lower the rope at pleasure. Two methods may be employed: a double wheel with buckets fixed in opposite directions; or a single wheel provided with suitable gearing or belts. The double wheel may be seen underground in Germany; it has sluices (*hatches*) which will turn the water on to either side, and there is a brake for controlling the motion. The winding drum is placed on the shaft of the waterwheel, and according as the water is turned on to the right-hand or to the left-hand side, the wheel revolves one way or the other.

When gearing is employed, a bevel wheel upon the shaft of the waterwheel drives a pair of bevel wheels, facing each other, which run loose upon the shaft of the drum. By means of a suitable clutch either of them can be brought into firm connection with the drum shaft, and so made to drive it in the required direction.

Steam engines employed for winding have usually two cylinders, either vertical or horizontal; the latter are preferred. It was usual at one time to put a pinion upon the crank-shaft and a spur-wheel upon the drum shaft; nowadays for quick winding

the drum is placed upon the same shaft as the cranks. Double cylinder engines are preferable to those with a single one, as for rapid work it is necessary to have more control of the engine than can be furnished by one of the latter type.

The engine must be provided with an adequate brake, and where the drum is worked by gearing, it is necessary to have a brake upon the drum shaft, because otherwise there would be no means of arresting the descent of the load in case of fracture of some of the cogs. Although many winding engines work without expansion, automatic expansion gear is common, and some of the engines are arranged so that the commencement and end of the run shall be worked with the full power of the steam, and the middle of the run expansively. Compound engines, and indeed triple-expansion engines, have been erected for winding purposes, though the advisability of employing them is questioned by some mining engineers; while fully admitting the value of the principle in the case of engines which are working constantly, such as those used for pumping, they contend that it is not advisable to complicate machinery which is performing very irregular work, and being constantly stopped and started.

Fig 186 represents a large horizontal twin tandem compound winding engine made by the "Gutehoffnungshütte Actien Verein fur Bergbau und Huttenbetrieb" of Oberhausen, Germany.

The engine has two high-pressure cylinders of 2 ft. 9½ in. (850 mm.) in diameter and two low-pressure cylinders of 3 ft. 11¾ in. (1200 mm.) in diameter; the stroke is 6 ft. 6¾ in. (2000 mm.), with a steam pressure of 8 atmospheres in the high-pressure cylinder at starting. The engine is capable of raising a load of 4⅓ tons (4400 kil.) at a speed of 40 to 50 ft. a second (12 to 15 m. per second) from a depth of 820 yards (750 m.).

The two winding drums are cylindrical in shape, each 27 ft. 10½ in. (8500 mm.) in diameter and 5 ft. 8¾ in. (1750 mm.) wide, and capable of receiving 930 yards (850 m.) of rope 2 in. in diameter (50 mm.).

Compressed air is largely employed when the hoisting engine has to be placed underground, and it is especially suitable for sinking intermediate shafts (*winzes*). Occasionally, as for instance at the Long Tunnel, Walhalla, in Victoria, all the hoisting of a mine is done by a compressed air engine.

Hoisting by electricity is as yet in its infancy, but already motors of considerable size are employed for winding purposes in mines, and the new engine for one of the shafts of the

Fig. 186.—Horizontal twin tandem compound winding engine, made by the "Gutehoffnungshütte Actien Verein für Bergbau und Huttenbetrieb" of Oberhausen.

Gelsenkirchen Mining Company in Westphalia will have a maximum capacity of 2800 h.-p.

A winding drum is usually a mere revolving cylinder around which the rope coils itself. An objection urged against the plain cylindrical drum is that it in no way compensates for the change of work required of the engine during the different phases of winding. To make this plain, suppose one end of the rope to be at the bottom of the shaft with the full load attached to it, whilst the other end is at the top with nothing but the empty cage. On starting, the engine has to raise not only the weight of the load of mineral, but also the entire weight of the rope hanging down the shaft, and in deep mines with large cages, this weight is by no means inconsiderable. In proportion as the full cage is raised, the amount of dead weight of rope to be lifted becomes less and less. Eventually the full and empty cages meet; the two portions of the rope then balance each other, and the engine has simply to overcome the action of gravity upon the mineral; later on, the rope of the empty cage is longer than that of the full one, and assists the engine in doing its work. At last, when the load is nearing the top, the drum is feeling the full weight of the rope of the empty cage.

Constancy of load is easily obtainable with the cylindrical drum by the simple expedient of adding a balance rope, that is to say, a rope hanging down the shaft with one end attached to the bottom of each cage. Provided that this rope agrees in weight with the winding rope, the counterpoising is perfect, for on each side, in every phase of the ascent or descent, there is always the same dead weight acting upon the drum.

With the same object in view the drum is sometimes made conical. The drum is so arranged that the diameter of the coil of rope increases as the act of winding up proceeds. The load at the bottom of the pit acts upon the drum shaft with a small amount of leverage: its leverage increases as the weight due to the rope diminishes. The reverse condition of affairs exists with the descending load. it has a large leverage while there is only a short length of rope hanging down the shaft, but as the weight thrown upon the drum increases, so the leverage diminishes. Intermediate between the conical and the cylindrical drum is one which combines the two systems; the conical end is used for beginning the wind and the cylindrical part for completing it (fig. 187).*

* "Die neue Fordermaschine der Tamarack Mining Company," *Gluckauf*, vol. xxxvi., 1900, p. 325.

When a flat rope is used instead of a round one, it is convenient, for the sake of distinction, to speak of the winding cylinder as a 'reel' or 'bobbin.' The flat rope coils upon itself,

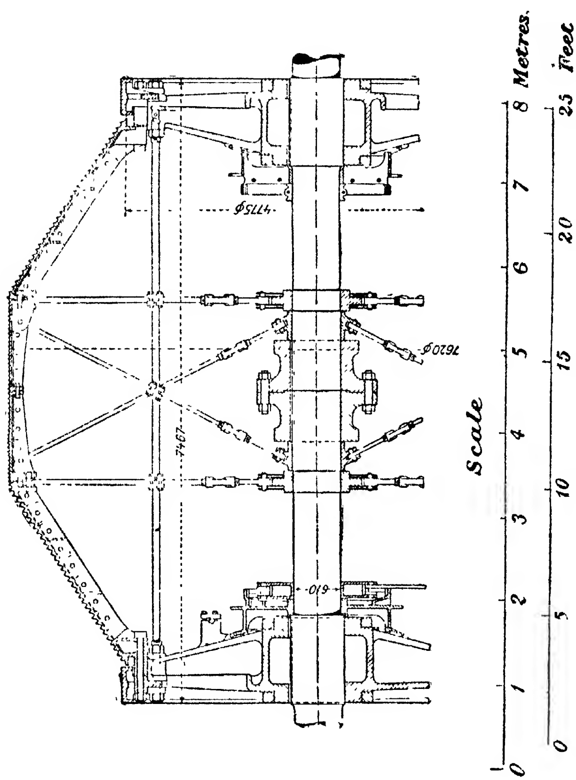


FIG. 187.—Section of winding drum, Tamarack Mine, Michigan, U.S.A.

and as the winding proceeds the diameter of the coil increases, if the cage is being raised, or decreases if the cage is being let down In this way there is a certain compensating action similar to that which is obtained with a conical drum; in other

words, at the moment of starting when the load is at the bottom, the smallest amount of leverage is exerted upon the driving shaft of the reel; whereas at the end of the wind, when the load is smallest it is exerting the greatest leverage.

The framework at the top of the shaft for supporting the pulley or pulleys is known by different names. It is called the headgear, pithead frame, or poppet heads (Cornwall). It may be constructed of timber, iron or steel (figs. 188, 189, 190,* and 191),† and metal pulley-frames are now usually seen at large mines where winding is conducted upon an extensive scale; at small mines and during sinking operations a timber headgear is common.

Winding pulleys have to be placed on the pithead frame in order to change the direction of the rope. Pulleys are made from 10 to 15 and even 20 ft. in diameter, in order to subject the rope as little as possible to sharp bendings, which would reduce its life.

(2) Ropes and Rope-Attachments.

Ropes are made of vegetable fibre of some kind, or of iron or steel wire. The vegetable fibres used are hemp and manilla, which are twisted into yarns; the yarns are laid together so as to form strands, and finally the strands are laid together to form the rope.

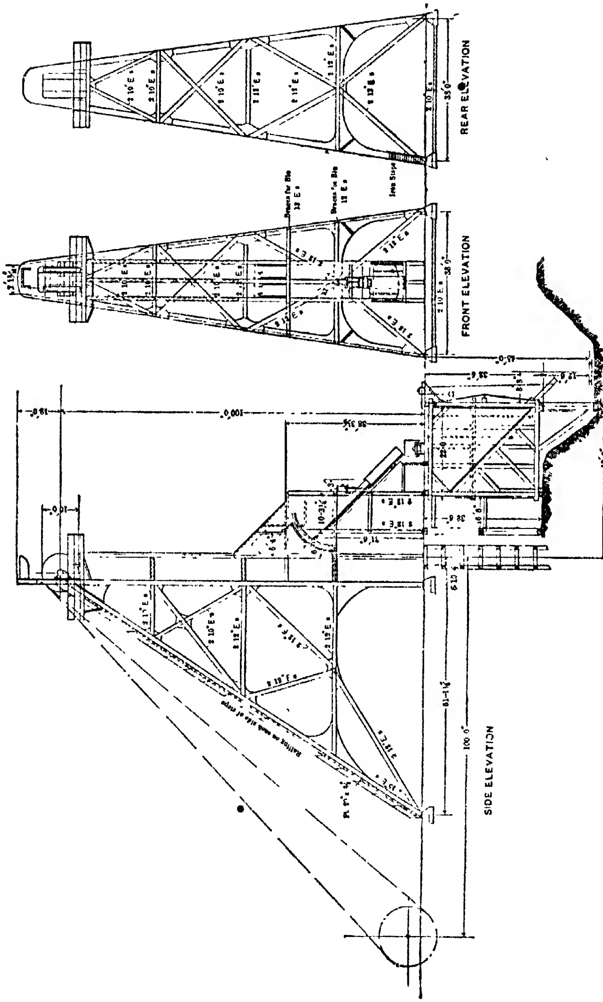
For winding by hand, in sinking small intermediate shafts (*winzes*), a hemp rope ⅞ in. in diameter and made up in three strands, is commonly employed. For heavier work, either a round rope of larger section is necessary, or a flat rope formed by sewing together several round ropes.

Iron has been superseded by steel for making wire ropes nowadays.

Steel wire winding ropes are usually composed of six strands and a central core of hemp, each strand being made up of seven wires (fig. 192). In the United States and in South Africa, a 'seven-nineteen' rope is often employed, *i.e.* a rope with seven strands, each composed of nineteen wires. In ordinary ropes the 'lay' of the strand is like that of hemp ropes; that is to say,

* "Steel Head Frame of the Parrot Mine, Butte, Montana," *Eng. Min. Jour.*, vol. lxxiii., 1902, p. 862.

† Nogara, "Descrizione dell' impianto idro-termo-elettrico della Miniera di Frongoch, Cardiganshire," *Resoconti delle riunioni dell' Associazione Mineraria Sarda*, Anno VI., No. 3, 1901.



FIGS. 188, 189, and 190.—Steel headgear and ore bins, Parrot Mine, Butte, Montana.

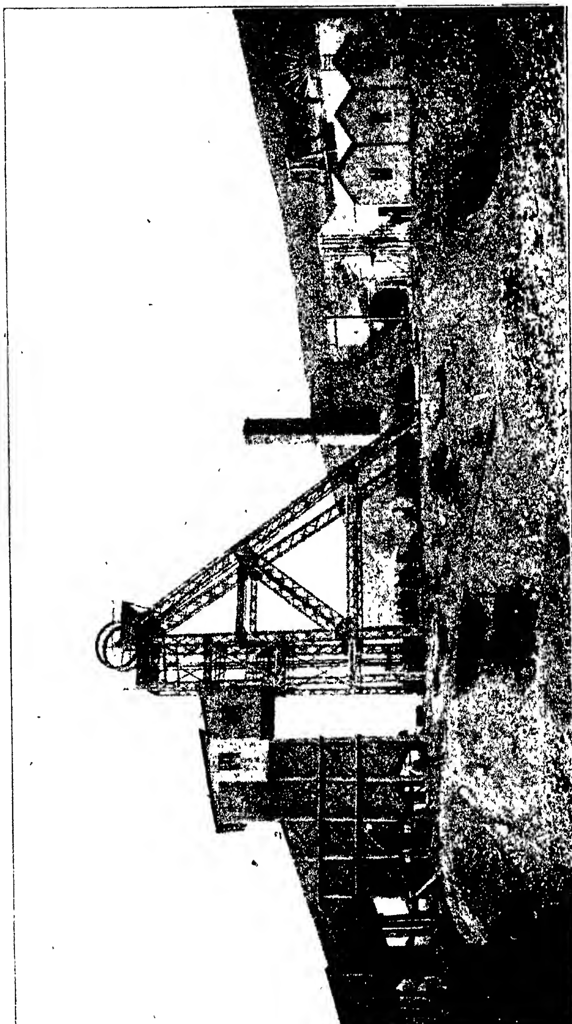


FIG. 191.—Pithead frame, Frongoch Mine, Cardiganshire, with electric winding engine of 125 h.-p. From a photograph by Mr G. J. Williams, H.M. Inspector of Mines.

the reverse of the lay of the rope (figs. 193 and 194). Lang has improved the method of manufacture by making the lay of the strand the same as the lay of the rope; the wires are less sharply bent, and present a longer wearing surface. The result is that whilst the wires of an ordinary rope wear quickly on the crown of the bend and break (fig. 194), Lang's rope, with its greater wearing surface, has a much longer life (figs. 195 and 196).

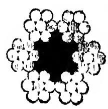


FIG. 192.—Cross section of a steel wire rope.

FIGS. 193 and 194.—Wire rope with the ordinary 'lay' before and after use.

In designing the 'locked coil wire rope,' the inventors departed entirely from the old traditions of manufacture. They considered, and very properly, that when dealing with a material like steel wire, which can be obtained of very great length, it is quite unnecessary to copy the methods suitable for the short fibres of hemp. As will be seen by fig. 197, nearly the whole of the section of the rope is made up of useful material. There are scarcely any spaces such as exist in the strands of an ordinary rope, and consequently for any given section the locked coil rope is stronger than a strand rope. It is very flexible and has a smooth uniform surface, which makes it look at a distance like a solid bar of iron. No one wire of the outer ring is more exposed to wear than the other; consequently there is not the danger of having broken wires, arising from the top of the crown

FIGS. 195 and 196.—Wire rope with Lang's lay before and after use.

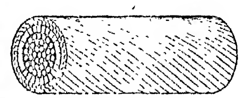


FIG. 197.—Locked coil wire rope.

being rubbed off by continual use. Another advantage is the absence of any tendency to twist, whereas the ordinary rope turns, and sometimes a good deal. On the other hand, the locked coil rope cannot be spliced, but sockets can be used for connecting one length to another.

In spite of sundry advantages the locked coil rope has not always proved so successful for winding purposes as was at first expected. The experience of Westphalian collieries is in favour of

FIGS. 198, 199, 200.—Flattened strand wire rope.

the flattened strand rope, in which the strands are oval, with the object of making the rope more nearly cylindrical than is possible with the ordinary method of manufacture.

For attaching the wire rope to the cage, or other winding receptacle, it is necessary to form a loop of some kind, which can be connected by means of a D-shaped link with a screw pin. Several kinds of attachment are shown in figs. 201, 202, and 203.

(3) Receptacles.

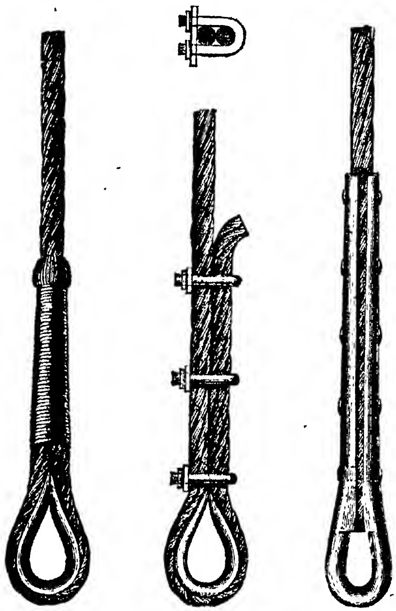
There are three kinds of receptacles used for raising the load in the shaft: (*a*) buckets (*kibbles*, *bowks*, *hoppets*), baskets or bags, swinging loose in the shaft and bailers; (*b*) buckets or boxes (*skips*) working between guides; (*c*) cages carrying one or more waggons.

The buckets are made of wood, sheet iron, or sheet steel. Various forms are used, viz., round, elliptical, or square, and the sides may be straight, or bulging in the middle. Fig. 204 represents a common form of sheet-iron kibble.

On the arrival of the kibble at the surface, the lander seizes an eye or ring at the bottom (fig. 204) by a pair of tongs suspended to a chain, and then gives the signal for the rope to be lowered slightly. The kibble turns over because it is suspended from the bottom, and its contents are shot into a tram waggon placed ready to receive them. During the operation of discharging the kibble, the mouth of the shaft should be covered by a hinged door, so as to prevent stones from falling down and injuring the filler in the *plat*.

In the exceptional case of a liquid, such as petroleum or brine, the mineral is lifted by a bailer (p. 51) or a pump. The bailers used at Baku are often 40 ft. in length.

The use of guides enables winding to be carried on more smoothly, safely and rapidly. The guides may be chains, wire ropes, bars of wood or round iron, or, lastly, iron or steel rails.



FIGS. 201, 202, 203.—Attachments or 'cappings' of wire ropes.*

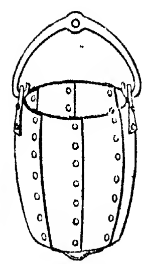


FIG. 204.—Winding bucket or kibble.

Chains are rarely met with; the commonest method of guiding in perpendicular shafts in this country is to hang two or more stout wire ropes from the top to the bottom of the shaft, and to provide the winding receptacle with eyes which pass over them. They are kept taut by weights or screws.

* Copied, by permission, from Messrs George Cradock & Co.'s figures.

Wire rope guides may be used even in the case of a kibble; a cross-bar with two eyes is attached near the end of the winding rope, though the kibble remains loose, it is so close to the cross-bar that it can swing but little. By fitting wire rope guides of this kind to perpendicular shafts originally worked with the ordinary loose kibble, winding can be carried on with greater speed and safety, whilst the cost of making the alteration is comparatively small. There is the further advantage that the shaft when provided with guides becomes available for raising and lowering the men.

We next come to the box of rectangular or circular section (*skip*), made of sheet iron or sheet steel. It usually has a sloping bottom, and is provided with a hinged door for discharging its contents, in some cases it is emptied by being turned over automatically on reaching the top of the shaft. The skip may be used in perpendicular, inclined, or crooked shafts. The guides or conductors are most commonly rectangular bars of wood, bolted to the end-pieces of the shaft and to the 'dividings' in the manner shown by figs. 113 and 114.

If the shaft is perpendicular the skip may be guided by two U-shaped shoes of iron, which clasp three sides of the conductor. If it is inclined the skip runs upon four wheels, as shown by fig. 205. In an inclined shaft the conductors sometimes have rails upon which the wheels of the skip run; in others the timber is not protected in any way.

When winding is going on from any particular level, a stop, such as a strong bar of iron, is put across the shaft to arrest the skip; the miner, standing in the *plat*, shovels the mineral into it, and gives the signal to have it drawn up as soon as it is filled.

A better plan is to adopt the arrangement explained in fig. 205, which will be easily understood. B is a strong plate working on a pivot which is put down to stop the skip: C is a pivoted hood turned over the mouth of the skip so as to prevent stones from falling into the shaft, and when this is in place the workman raises the door of a large bin or hopper, and allows part of its contents to run out. The hopper has been filled by tipping waggons from the line of rails in the level above.

On reaching the surface a hinged sloping door is turned over the shaft, and the skip is lowered a little until it rests upon it; the workman (*lander*) then knocks up the bolt retaining the door of the skip, and the contents fall out into the tram waggon placed to receive them. The lander replaces the bolt, the skip is raised slightly, the door pulled back, and the skip lowered once more into the shaft.

All these operations cause a needless waste of time, and the modern practice is to employ self-discharging skips, by means of which very large quantities of mineral can be dealt with quickly and at very little cost. Where the winding shaft is inclined, the skip is drawn by a long bow (fig. 206). The two hind wheels are

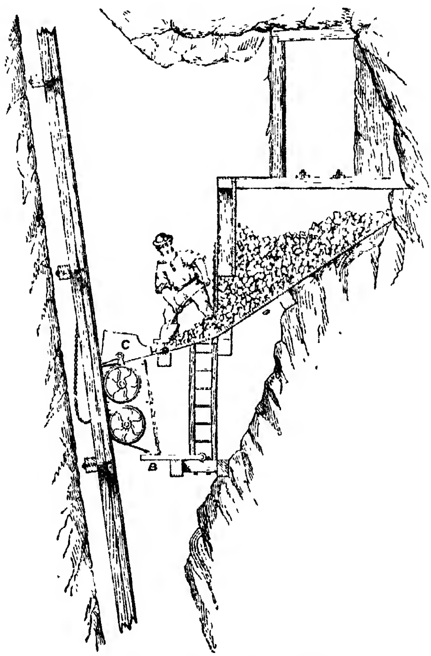


FIG. 205.—Skip in inclined shaft.

very much broader in the tread than the two in front, and soon after reaching the surface they are caught by two special rails, whilst the front wheels travel on the ordinary guides. This causes the skip to tilt up and discharge its contents without the intervention of any workman. Self-tipping skips are likewise employed in vertical shafts.

The system of winding by a cage is adopted almost universally

at collieries; it is likewise very general in mining seams of ore, and is not uncommon in the case of veins and masses.

The cage, as its name implies, is a more or less open receptacle, which receives the waggon used underground, and conveys it to the surface.

Figs. 207 and 208 represent the light and simple cage used at the mines on the Comstock lode;* it is a mere timber platform 5 ft. by 4 ft., resting on iron bars and supported by iron rods on each side. It is provided with a sheet iron bonnet to protect the men inside from anything falling down the shaft, and also with safety catches, which come into play if the rope breaks.

The hand levers *k k* at the ends of the cage, raise up blocks which keep the tram waggon in its place during the ascent or descent; *g g* are the guides for the ends of the cross-bar *b*; *c*, the bar working the teeth *t t* by levers; *f*, shoe or ear embracing the

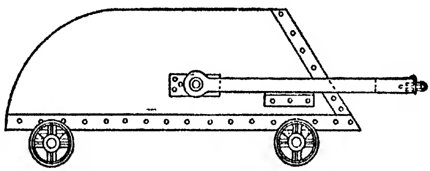


FIG. 206.—Self-discharging skip for an inclined shaft.

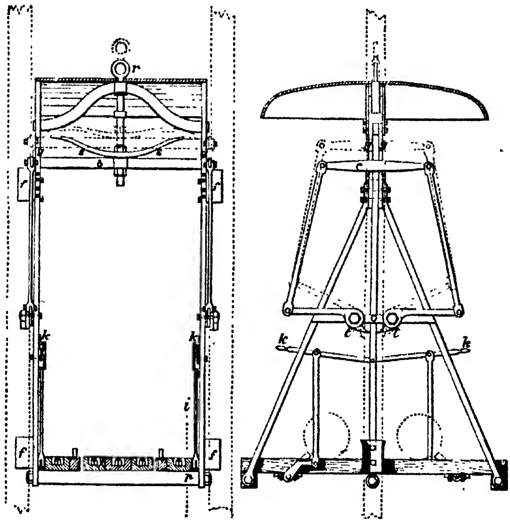
guide rod, or conductor, in the shaft; *r*, the lifting bar; *s*, a strong spring which comes into operation if the rope breaks.

The length and breadth of the cage are limited by the size of the shaft; where it is desired to raise a larger quantity of mineral than can be contained in one waggon, or two placed side by side, the carrying capacity of the cage may be increased by constructing it with two or more platforms, technically called decks. Cages are sometimes seen with as many as twelve decks.

As a rule the full waggon is drawn out of the cage at the top of the shaft, and is trammed to some convenient place where it is tipped; of late years the ingenuity of American inventors has led them to introduce methods of tipping the waggon automatically on reaching the surface without leaving the cage, in order to save time in winding. Russell and Parson's automatic dumping cage, said to be doing good work in the United States, has its platform movable upon an axle underneath, which allows it to be tilted on

* J. H. Hague, "Mining Industry," *Rep. U.S. Geol. Expl. of 40th Parallel*, vol. iii., Washington, 1870, Plate vii., p. 119

one side or the other. The cage has the usual shoes at the bottom and top, which cover $5\frac{1}{2}$ in. of the wooden guides or conductors; the tilting platform has its own two separate shoes, which clasp only $2\frac{1}{2}$ in. of the guides. Whilst the cage is in the shaft, the platform is held in a horizontal position by its shoes running upon the guides. At the surface the wooden conductors are cut away for a depth of $2\frac{3}{4}$ in., so that, although the cage itself is guided, the small shoes are free to move sideways and



FIGS. 207 and 208.—Cage, Comstock Lode, Nevada, U.S.A. Front elevation. Side elevation.

permit the tilting, when the platform touches a properly arranged stop. The flap door of the waggon is released automatically at the same time, and the mineral is shot out into a large bin at the pit top.

(4) Keps, Signals and Indicators.

On arriving at the surface the cage is usually lifted a little higher than the landing platform, and supports of some kind (*keps*) are brought underneath it, so as to hold it up while the

full waggon is drawn off and the empty waggon pushed on. The cage is then slightly raised, the supports (*keps*) are drawn back by a lever, and the descent begins.

It is necessary to have some means of communication between the various 'on setting' places and the top of the shaft, so that the man at the bottom (*on-setter*, *hooker-on*) may be able to inform the man at the top (*banksman* or *lander*) when he is ready for the cage, skip, or kibble to be drawn up.

In shallow workings shouting is sufficient; when the pit becomes deeper a speaking tube is sometimes put in, but the commonest method of signalling is by a cord made of galvanised wire. The cord is carried round curves and corners by means of cranks similar to those used for house bells, only larger and stronger, and when it is pulled by a lever at the bottom, it moves a hammer which strikes a bell at the surface.

Electric bells are common. Telephones of various descriptions are sometimes used, but for ordinary purposes of winding the simple signal given by a bell is quite sufficient.

In addition to the signal for starting and stopping, there is an indicator which shows the engineman the exact position of the load in the shaft.

The arrival of the load at the surface may be brought to the engineman's notice in several ways: by a mark on the rope, by the pointer on the indicator, and by some audible signal worked automatically by the winding engine.

(5) Safety Appliances.

In rapid winding with large drums, a slight inadvertence on the part of the engineman may cause the load to be drawn up against the pulley, and this is what is commonly known as 'over-winding.'

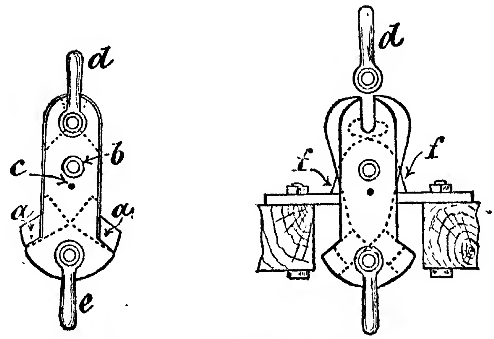
Various plans have been devised for preventing disastrous results if an accident of this kind occurs; one of them consists in interposing between the rope and the cage a special appliance, called a detaching hook, which will sever the connection between them, allow the former to be wound up, and at the same time hold up the latter safely without damage to the load or persons inside.

Among others the detaching hook of King and Humble is well known (figs. 209 and 210). It consists of two outer cheeks or sides, containing two inner plates which can move about a central bolt (fig. 209). Each plate has a wing, *a*, projecting beyond the framework. When in use the two plates are prevented from coming apart by a small pin or rivet, *c*.

If the cage attached to *e* is wound beyond a certain height, the

detaching hook is drawn into a round hole in a strong iron plate (fig. 210), and when the projecting wings *a a* strike against this plate, they are forced to move inwards, the rivet is cut, the shackle *d* at the end of the rope is set free, and the two catches *f f* are thrown out; these drop upon the plate and hold the cage firmly suspended.

The detaching hook does not prevent overwinding, for it does not come into play until after the cage has been wound up too high; at the best it can prevent the overwind from having disastrous effects; and further, it is no safeguard for the descending cage, which may be dashed violently against the bottom of the shaft.



FIGS. 209 and 210.—King and Humble's detaching hook. Shackle fixed. Shackle released.

Many mining engineers, and especially our Continental brethren, are therefore of opinion that some speed checking appliance is desirable, which will come into action if the cage is approaching the surface too rapidly, and stop it altogether before it has been lifted as high as the pulley. Among them may be mentioned the clever appliances of Reumaux, Villiers, Wéry, Bertram and Cobbold, and Paschke and Kastner.

Much ingenuity has been displayed by various inventors during the last fifty years, with the object of providing some sort of catch which will come into play if the rope breaks, grip the guides or conductors, and so prevent the cage or skip from falling down the shaft.

Many of them are actuated by a spring, and one form has already been mentioned while describing the cage used on the Comstock lode (figs. 207 and 208).

While the load is hanging from the rope, the spring *s s* is drawn into position shown by the dotted lines by the lifting bar, *r*, the eye of which is figured in its two positions. The bar *c* is drawn up at the same time, and the teeth *t t* are held apart and kept clear of the guides. If the rope breaks, the spring forces down the bar *b* and with it *c*; the teeth jam into the wooden conductor, and the cage is arrested and held firmly.

On the whole, these appliances are not regarded with so much favour in this country as they are on the Continent; the objections made to them in England are that they sometimes fail to do their work at the right moment, and at other times come into action when not required. English engineers, as a body, are more inclined to endeavour to avert disasters by refusing to employ any ropes but the very best, and by discarding them after a given working period, even if they apparently show few outward signs of deterioration.

The most novel hoisting apparatus is that of M. Blanchet, which was regularly at work at Epinac in France for some years. A large pipe was fixed in the shaft, and in it was placed a piston from which was suspended a cage carrying waggons. By exhausting the air above the piston the load was gradually forced up by the atmospheric pressure below it. The shaft was 660 yards deep, and the pipe was 5 ft. 3 in. in diameter, made up of a succession of cylinders of sheet iron about $\frac{1}{3}$ in. thick and 4 ft. 1 in. high, joined by flanges and bolts. The 485 rings composing the long pipe weighed altogether 418 tons. The cage had nine decks, and arrangements were made for unloading three at a time; each waggon held half a ton, so that the total useful load was $4\frac{1}{2}$ tons. The speed of hoisting was 20 ft. per second. If two hoisting pipes are connected, the dead weights may be made to balance each other, and the power required is simply that which is necessary to overcome the weight of the useful load. The advantages claimed for this system are: (1) The possibility of hoisting from depths at which rope winding would no longer be practicable; (2) getting rid of costly ropes and dangers connected with rope-winding; (3) better utilisation of the engine power; (4) improvement of the ventilation and diminution of the amount of fire-damp. At present Blanchet's apparatus is no longer employed, but the disuse of the pneumatic method is in no way due to any difficulty in making it work satisfactorily.

CHAPTER IX.

DRAINAGE.

I PROPOSE to deal with the subject under the following headings: (1) Preventing inflows of surface or underground water; (2) Drainage tunnels; (3) Siphons; (4) Winding machinery; (5) Pumps; (6) Co-operative drainage.

The great importance of drainage is not always realised. A few instances will serve to show that draining a mine may often be a more troublesome and costly operation than winding up the mineral. At the Mansfeld copper mines the steam machinery employed in 1893 generated altogether 11,672 h.p., of which 7730 h.p., or roughly speaking two-thirds, were required for pumping. In 1892 the owners of the Milwr lead and zinc mine in Flintshire had to pump up about 160 tons of water for every ton of undressed ore drawn to the surface; a few years ago, in the area placed under the South Staffordshire Drainage Commissioners, 27½ tons of water were being pumped for every ton of coal, etc., extracted; and in some mines in Pennsylvania the proportion is five tons of water to one ton of anthracite.

(1) Preventing Inflows of Water.

In mining, as elsewhere, "prevention is better than cure," and care should be taken to prevent as far as possible the entry of water from the surface, for it has been abundantly proved in many cases that the bulk of water with which the miner is burdened is due to the percolation of rain-water.

It often happens that the mineral was quarried near the surface before underground mining was resorted to, and in that case there is always the danger of the old open pits forming 'sinks,' so to speak, which will collect water from the neighbourhood and let a considerable quantity find its way into the workings. To avoid this, the surface must be drained; special care is imperative where

the ground is cracked by subsidences, and the neighbouring streams should be examined and the water carried along in launders or other safe channels, if their beds cannot be made stanch by filling the fissures with concrete.

In addition to preventing the access of water from the surface, it is advisable to cut off underground inflows as far as practicable. In Chapter V. a description was given of impervious linings for shafts; and where water can be shut out by 'tubbing' or by 'coffering,' the mine-owner is saved the constant expense of pumping; indeed, he is sometimes thus enabled to work deposits which he would not be able to reach if he had to fight against the enormous streams issuing from certain strata. Natural springs and influxes from adjacent abandoned workings are sometimes shut out by dams—that is to say, artificial stoppings—placed in levels or shafts. They may be made of timber, brickwork, masonry or concrete, and, when intended for temporary purposes, of iron.

The first consideration in erecting a dam is the choice of a suitable site, for it is useless to take the trouble to put in a stanch stopping, unless the ground is firm enough to support it, and free enough from cracks to prevent the water behind it from finding its way round to the front.

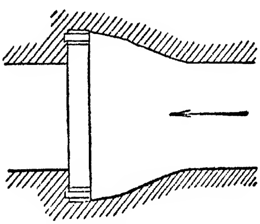


FIG. 211.—Timber dam in a level.

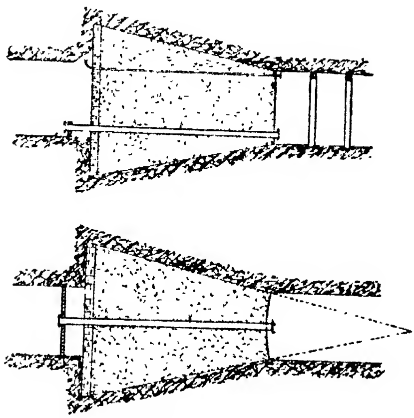
If the ground is thoroughly strong, a dam may be put in by cutting a recess in the sides of the level, as shown by fig. 211, and stopping the water back by a wall made of horizontal balks of timber. Oak is usually chosen for the purpose. Before the timber is put in, the rock is very carefully dressed until the surface is perfectly smooth, and ready to receive a similar surface of wood. Each balk is wedged up against the side just in the same way as a wedging curb, and the joints between the separate balks are caulked.

For heavier pressures the spherical dam is available; it is constructed of wooden logs placed longitudinally and wedged very tightly. A wooden dam of this kind has the advantage that it will yield a little if there are movements of the ground, whereas a dam constructed of bricks might become cracked and leak so badly as to become useless; the wooden dam is more easily repaired. Concrete dams are very readily put in, and figures

212 and 213 represent one erected lately at a colliery in Belgium.*

(2) Drainage Tunnels.

Where the contour of the country permits it, mines may be drained naturally by tunnels which have just enough slope to bring out the water. A tunnel of this kind is generally known as an 'adit,' or 'day-level.' In hilly countries mines are often worked entirely by adits, and even for the deeper



FIGS. 212 and 213.—Vertical section and horizontal section of a concrete dam in a level.

workings the adit presents several advantages: it lessens the quantity of water percolating into them; it diminishes the height to which water has to be pumped; its outflow may be utilised for generating water power; and lastly, it affords a natural discharge for water used for driving hydraulic engines underground. On account of these very important advantages, some long and costly adits have been driven in certain metalliferous districts.

Thus in the Hartz, the Ernest Augustus adit or drainage tunnel ("Ernst August Stolln") has been driven a distance of

* Habets, "Note sur l'emploi du Béton dans les Mines," *Revue Universelle*, vol. l., Liége, 1900, p. 39.

nearly $6\frac{1}{2}$ miles into the Clausthal district. The total length of the adit, including its branches, is no less than 14 miles. It intersects many of the lodes at a depth of 400 yards from the surface. The total cost of this adit is estimated at £85,500.*

Another long adit is the celebrated "Rothschonberger Stolln," which unwaters some of the most important mines at Freiberg in Saxony. The length of the main or trunk adit is more than $8\frac{1}{2}$ miles; the gradient of the greater part of it is only 1·18 inch in 100 yards. Branches of this adit among the mines are more than 16 miles in length, so that the total length of the main tunnel with its ramifications amounts to about 25 miles. Most of the mines are now drained by it to a depth of 250 to 300 yards. The cost of the main tunnel was £359,334, or nearly £24 per yard, but this includes the cost of eight shafts, heavy expenses for pumping from these shafts, the walling of the adit for $\frac{3}{4}$ mile, and all general expenses. The length of time occupied in driving this adit was thirty-three years.

The "Kaiser Josef Erbstolln," in Hungary, is another remarkable mining tunnel, which was commenced in 1782 and completed in 1878, at a total cost of 4,599,000 florins. It is $10\frac{1}{4}$ miles in length, extending from the river Gran to the town of Schemnitz, where it intersects the lodes at depths varying from 300 to 600 yards according to the contour of the surface.

In Bohemia I may mention the "Kaiser Josef II." adit which drains the Příbram mines. The length from the mouth to the Stefan shaft is $4\frac{7}{8}$ miles, and the side branches bring up the total length to $13\frac{5}{8}$ miles.

The great adit of the Mansfeld copper mines was begun in 1809, and was seventy years in course of construction. It reaches from Friedeburg on the Saale to Eisleben. The first part was driven across the measures and is, in fact, a cross-cut, and it was then continued along the strike of the cupriferous seam; the total length is now 21 miles. All the workings below its level extending for a distance of more than 11 miles have their water pumped into it. The adit was driven with a rise of 1 in 7200. It is 9 ft. 10 in. high and 6 ft. across in the middle, where it is the widest.

The adit at Monteponi,† in Sardinia, is $3\frac{3}{4}$ miles in length, and reduces the height to which the water has to be pumped by about 160 ft.

* Bauerman, "Note on the new Deep Adit in the Upper Hartz Mines," *Trans. Min. Assoc. Cornwall and Devon*, 1868, p. 11.

† Pellati, "I Progressi nelle Industrie Minerarie e Mineralurgiche Italiane," *Industria*, vol. v., 1891, p. 637.

A most important adit in France is now nearing completion; it is being driven from the sea near Marseilles to unwater the important lignite mines of Gardanne. The adit when finished will be 12 miles long, with a gradient of 1 in 2000.

In the United States many adits of great importance have been constructed, amongst which should be mentioned the Sutro tunnel, which enters the working on the Comstock lode at a depth of 1700 ft. below the surface. The length of the main tunnel is 3⅞ miles, and the total cost $2,096,566. Several large adits are now being driven in Colorado; the Newhouse tunnel is one of the best known.

Natural drainage is often impossible or insufficient, and in such cases it is necessary to resort to artificial means, viz., siphons, winding machinery or pumps.

(3) Siphons.

These are used for draining mines in a few special cases in which the barrier over which the water has to be raised is very decidedly less than 33 ft.

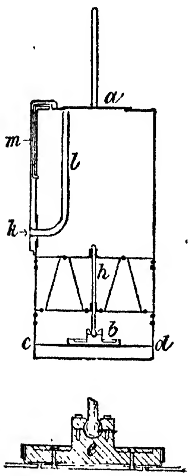
(4) Raising Water by Winding Machinery.

If the quantity of water is not excessive, it is often convenient to use the winding machinery, and draw up the water in special buckets (*water barrels, bailers*) or tanks. The bucket may be tilted over on reaching the surface, or it may be emptied by opening a valve at the bottom.

This means of raising water is commonly adopted in sinking a shaft, when it may be desirable to wait till the whole or a portion of the pit is completed, before putting in the final pumping machinery. The water is usually lifted by hand into the bucket or tank, an operation involving a good deal of labour. Some of the bailing may be avoided by collecting as much as possible of the inflow in a cistern above the bottom of the shaft, and drawing off its contents by a hose into the bucket. This device is of no use for the water actually at the bottom, but bailing may be dispensed with even in this case by the adoption of an ingenious arrangement invented by Prof. Galloway, and applied very successfully by him in sinking a shaft near Cardiff* (figs. 214 and 215).

* "Sinking Appliances at Llanbradach," *Trans. South Wales Inst. Eng.*, vol. xvi., 1888, p. 117.

He uses a cylinder with a valve at the bottom as a water barrel. When it arrives at the bottom, a piece of hose is attached by which communication can be effected with a pipe coming down the shaft and through which the air is being exhausted. The valve in the bottom of the cylinder opens and the water rushes in. A glass water-gauge shows when the barrel is full enough, and it is then immediately drawn up. On arriving at the top of the pit, it is lowered on to a trolley carrying a projecting conical block of wood, which knocks up the valve in the bottom and allows the contents to run out.



FIGS. 214 and 215. — Galloway's water-barrel.

a, door for entering barrel if required; *b*, flat cast-iron valve attached to the spindle *h*; *c d*, bottom plate of the barrel; *e*, section of the valve showing universal joint attachment; *l*, water pipe, provided at the end *k* with a coupling, to which the suction hose is attached; *m*, water-gauge.

When there are means of allowing the water-barrel to plunge either into a collecting pit (*sump*) or into a cistern, it may be filled automatically, and it is easy to make it self-discharging. Prof. Galloway's arrangements are shown by figs. 216 and 217. The former represents his automatic water tank with one side partly removed: *a* is the winding rope, *b* the tank, which is guided in its descent by the studs *c* (fig. 217) running upon the guide ropes *e*. At the surface the tank is further steadied by side-grooves, made of angle-irons *d*, which clasp the studs. When the tank is lowered into the cistern, the valve *k* opens of itself and lets the water rush in. The tank is then wound up to the top, where the short lever at *o* comes in contact with a piece of timber *p*; the rod attached to the valve is lifted, and the water rushes out by the sloping mouth *f* into a wooden trough or launder *m*. The bar *p* is movable about the point *q*, but it is kept down by the weight *u* attached by the chain *s*; *t* is one of the pieces of timber to which the fixed guides are fastened; and lastly, *w* is the suspending bow which passes quite round the tank and forms a projecting loop at the bottom. This bow protects the bottom of the tank while it is standing in the cistern. The tank holds 212

gallons, and can be drawn up twenty-four times an hour from a

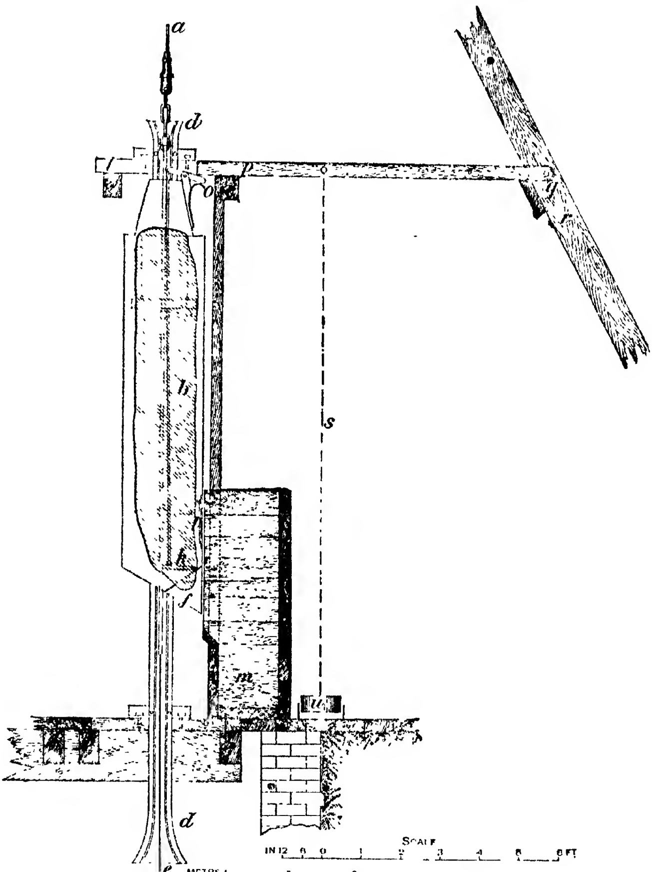


FIG. 216.—Galloway's water tank.

depth of 190 yards; it is therefore capable of raising 5000 gallons in that time.

The arrangement just described was employed by Prof. Galloway when sinking, but it is equally available as a permanent method of drainage when the quantity of water is not considerable. The water is allowed to accumulate in a sump at the bottom of the shaft during the daytime, for instance; and at night, when no mineral is being wound, the ordinary cage is taken off and the water barrel substituted for it. The water-barrel is also useful as an auxiliary, when the ordinary pumping machinery of a mine is unable to cope with some unusual influx of water, or has to be stopped for repairs.

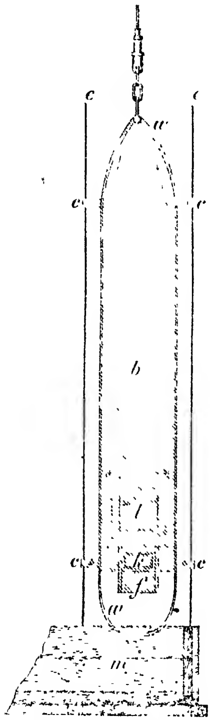


FIG. 217.—Galloway's water tank.

(5) Pumps.

The principal method of extracting water from underground working is by pumping.

The varieties of pumps used in mines are numerous. In small sinkings, hand-pumps, either direct-acting or rotary, may be applied; jet pumps, worked by steam, water, or air, are sometimes seen, and pulsometers are common in certain special cases; but when we examine the permanent machinery erected at large mines of considerable depth, we find that the prevailing types of pumps are few.

They may be arranged in two classes according as the prime mover is above or below ground.

The prime mover on the surface may be driven by wind, water, steam, gas, or petroleum. Windmills have the disadvantage, which is often fatal, that the power is not constant; the same may be said of water power derived from brooks and rivers, which sometimes dry up; but the two cases are different. Streams dry up slowly and gradually, whilst air currents spring up or die away suddenly. By erecting an auxiliary engine, which can be set to work if the wind fails, the evil is overcome; and this remedy is

adopted at the [illegible] mines in Anglesey, where a windmill has been in use for many years for working pumps. The granite quarries in Guernsey are nearly all drained by small windmills.

Water power was for a long period the principal agent employed in draining mines, and it still is of the greatest use in many districts, reservoirs being constructed to collect and store the rainfall.

Water power is applied to pumping machinery by water-wheels, turbines, and rotary or non-rotary water-pressure engines. Excepting in the case of the latter, the rotary motion has to be converted into a reciprocating motion by a crank; and furthermore, with turbines the speed must be reduced very considerably by intermediate gearing.

Overshot wheels are the commonest prime movers for working pumps by water power; they are frequently from 40 to 50 ft. in diameter, and at the Great Laxey mine, in the Isle of Man, one of the wheels is no less than 72 ft. 6 in. in diameter and 6 ft. in the breast. The power is conveyed from the water-wheel by a connecting rod to a quadrant or 'bob,' like a bell-crank, placed above the shaft; and when, owing to the contour of the ground, the wheel has to be erected at a distance, it is often connected to the bob by the so-called 'flat rods,' which are beams of wood, bars of iron, or pieces of wire rope. They are supported by pulleys or upright oscillating beams, and travel backwards or forwards with the motion of the crank.

Water-pressure engines share with turbines the advantage of being able to utilise any amount of fall, and direct-acting water-pressure engines can be applied immediately to the main rod of the pumps.

Steam is, however, the power used *par excellence* for working pumping machinery, and the great inventions of Newcomen and Watt owed their birth to the necessities of mines, which could no longer be drained by the water power available on the spot.

The type of engine known as the Cornish engine is a single-acting condensing-beam engine, working expansively, having the number of strokes regulated by an arrangement called a cataract. The cylinder of the Cornish engine is sometimes inverted and stands over the shaft, the main rod of the pumps being attached directly to the piston rod.

Where coal is very expensive owing to the cost of carriage, a petroleum engine may be a convenient source of power for pumping on a small scale.

The power generated at the surface is transmitted to the pump

by rods, compressed air, water, or electricity. The rods are preferably made of wood, but wrought iron or steel has been used.

Wooden rods in this country usually consist of pitch pine beams of square section, united by plates of iron or mild steel (*strapping plates*, *a*, *b*, *c*, fig. 218), which are held together by bolts, the butt end of one beam being brought against the butt end of the next.

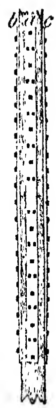


FIG. 218.—Pump rod showing joint with strapping plates.

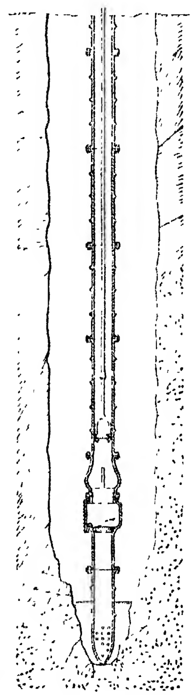


FIG. 219.—Lifting pump.

The iron or steel rods are either solid bars of round iron or steel, or beams built up from angle iron or angle steel, so as to obtain the desired stiffness without undue weight.

The long beam, made up of a succession of pieces, constitutes what is called a main rod or spear rod. It hangs down the shaft, either from the end of the beam of the engine, or from a quadrant when the cylinder of the pumping engine is horizontal. Where the shaft is inclined, the main rod has to be supported at suitable intervals by cylinders of cast iron or steel, known as 'shaft rolls.'

The main rod just described transmits the motion of the engine to a pump or several pumps in the shaft. These pumps are of two descriptions: either lifting pumps or force-pumps. The lifting pump or drawing lift (fig. 219) consists of the wind-bore or suction pipe, the clack-piece or valve box, the clack-seat piece, the working barrel, the bucket with its rod, and the column.

The wind-bore, or snore-piece, as it is sometimes called, is a

cylinder of cast iron, terminating in an egg-shaped or a flat bottom, with a number of holes through which the water is sucked up into the pump.

The clack-piece is a short cylinder of cast iron with a flat side door fastened by bolts, for the purpose of getting at the valve. It receives the seat on which a clack or valve works.

The clack seat piece is not always used; but it is often put in as a matter of precaution, in case the regular valve should accidentally fail while the pumps are under water.

The working barrel is a cast iron cylinder, carefully bored so that the bucket may work smoothly and exactly; occasionally it is bushed with brass.

The bucket is merely a moving valve, consisting usually of a hollow cylinder of cast iron, surrounded by a band of leather or guttapercha, and carrying a leather clack. The rod to which it is attached may be of wood or iron, and it may work either inside the column or outside. Fig. 219 shows the commoner method in this country, though the system shown in fig. 220 is employed both here and on the other side of the Atlantic. S is the wind-bore or suction pipe; V the fixed clack or valve; P the bucket with its valve *r*, moving in the working barrel. The rod to which it is fixed passes through the stuffing box *g*, and is connected to the wooden rod R. The column of pipes, made of riveted sheet iron, through which the water is lifted, is shown by C. Three sheet-iron cylinders riveted together form one section. Each section is provided at both ends with a cast-iron flange, and two adjacent sections are fastened together by bolts. The cast iron pieces H carry the stuffing box, and join the column to the working barrel. Lap-welded sheet-iron pipes may take the place of the riveted pipes of the figure.

The column of pumps in this country is

Fig. 220.—Lifting pump employed at mines on the Comstock lode.*

* Hague, "Mining Industry," *United States Geological Exploration of the Fortieth Parallel*, Washington, 1870, p. 121.

generally made of cast iron pipes with flanges. Pipes of sheet iron and steel have the advantage of lightness, an important matter when transport is expensive.

The force pump used in mines, known as the plunger pump (fig. 221), consists of a solid piston (*plunger*) working through a stuffing box in a long cylinder standing upon a special casting known as the H-piece. This is so called because it is made up of two parallel cylinders, like the two upright limbs of the letter **H**, which are connected by a horizontal pipe like the cross-bar. The H-piece has a valve immediately above the wind bore or suction-pipe. In the figure the wind-bore is flat ended because it is resting in a cistern. Above the H piece comes the door-piece with another valve, and then a series of pipes, the 'column,' generally of cast iron, but sometimes, as already stated, of wrought iron or steel.

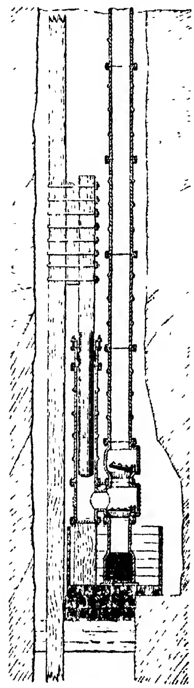


FIG. 221.—Force pump or plunger pump in shaft, vertical section.

The plunger pump can claim superiority over the lifting pump for several reasons; it is less likely to get out of order, and, if it does begin to fail, its shortcomings are more quickly perceived and more easily remedied.

In cases where the mine is being continually deepened, a process going on continually in vein-mining, a lifting pump is fixed at the bottom because it can so easily be lengthened; it lifts the water into a cistern in which stands the wind-bore of the plunger pump (fig. 221), and the remainder of the pumping is done in stages by a succession of force pumps, the wind-bore of each force pump standing in a cistern fed by the next one below it.

The Rittinger pump is an important type which has been introduced on the Continent in order to remedy one of the defects of the ordinary pumping plant, viz., its intermittent action. The Cornish engine makes a sudden start, the 'outdoor' end of the beam goes up, and with it the main rod and the plungers;

then comes a pause, and all this time no useful work of raising water is being done. Lastly, the beam and the main rod slowly descend and the plungers force up water. The actual work of pumping proper is accomplished in a short part of the time occupied by a double stroke. It is evident that a smaller engine doing work continuously would be just as efficient as the large one acting at intervals. The Rittinger pump is a differential pump, with two hollow plungers, one fixed and the other moving. Its action cannot be understood without a figure; suffice it to say that water is discharged continuously both on the down and on the upstroke.

The weight of the main rod with its strapping plates or other connections is greater than is required for the purpose of forcing

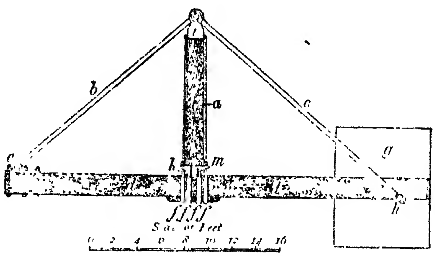


FIG. 222.—Balance bob.

up the column of water in the pumps, and overcoming the friction of the various parts of the machinery. It becomes necessary, therefore, both in order to avoid useless waste of power in lifting the main rod, and to prevent its descending with too great a speed, to counterbalance so much of the weight as is not actually employed in doing useful work. The commonest form of counterbalance is a 'bob,' such as is shown in fig. 222. It is a beam, *d d*, working upon pivots (*gudgeons*) *k*, which lie in brasses; the end *e*, called 'the nose of the bob,' is attached to the main rod by a long connecting rod, whilst *g* is a box which is filled, or partly filled, with old iron or stones. The beam is stiffened by the upright 'king post' *a* and the straps *b c*: *f f f f* are staples and glands fastening the casting *m* to the beam, and *i* is the 'bishop's head' at the top of the 'king post.' Cast iron beams, precisely like the beams of certain steam engines, fulfil the same office in some mines, and the counterbalance is a huge piece of cast iron.

There is usually a 'balance bob' at the surface, and others are fixed at intervals in large recesses (*bob plats*) cut out in the sides of the shaft.

Provision must be made for a possible breakage of the main rod, which might have a very disastrous result. If such an accident happened without any of the ordinary safeguards, the beam would come down with great force and play havoc in the engine house, whilst the main rod dropping in the shaft would be sure to do damage to the pumps. The 'indoor' end of the engine-beam is therefore fitted with two projecting arms of iron, which come down so as almost to touch two strong timber beams

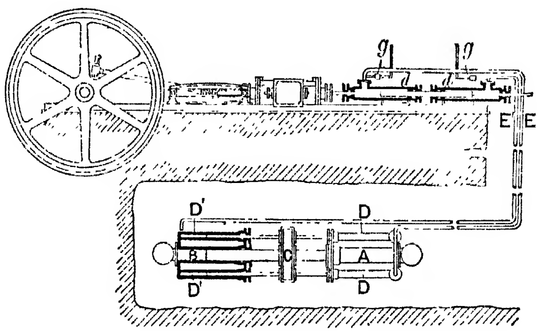


FIG. 223.—Moore's pump with hydraulic transmission of power.

at every stroke; if a breakage happens, these arrest the motion of the engine-beam before it has had time to do any harm

Catches are also fixed in the shaft; they are strong beams of timber stretching across the shaft and resting in good 'hitches,' with the main rod working between them. 'Wings' attached to the main rod are so adjusted that they all but touch the beams at the end of each down-stroke of the rod. A catch of this kind limits the possible fall of the main rod to the length of the stroke.

The cumbersome nature of rods, with all their heavy strapping plates, catches and counter-balances, has long made the miner seek for some simpler method of transmitting power. The problem has been very successfully solved by Moore's hydraulic system of transmission, adopted in Scotland and the United States. A horizontal engine erected at the surface (fig. 223) works two rams *d d'*, and these force water down two pipes E E' to the

underground rams D D, D′ D′; $g\ g$ are valves through which water is supplied to the pressure pipes from cisterns. The plungers of D D and D′ D′ are attached to a cross-head C which carries the two pumping plungers A and B. The ram d forces water into the two power rams D, and the ram d' into the two opposite rams D′. If water is being driven down by d, the cross-head C will be moved towards B; the mine water will be forced up by its plunger and sucked up by A. At the same time the power water in D′ D′ will be driven back a little way, ready to move in the opposite direction as soon as d' makes its stroke. The underground pump thus follows precisely the movement of the engine at the surface. The pressure in the transmitting pipes is not less than 1000 lbs. per sq. in., and this enables small pipes to be used. Kaselowsky's system is similar.

Where compressed air is furnished to the workings generally, for the purpose of driving rock drills, coal-cutters, winches, etc., supplies may be taken from the mains in order to operate small direct acting pumps. As pointed out in Chapter IV., there is great convenience in using air in situations far removed from the pit bottom, where steam is practically out of the question, and air has the further advantage of causing no sparks, a danger which may be apprehended with electricity.

The simplicity and efficiency of electrical transmission are daily becoming more and more apparent to the miner, and it is not surprising to find an increasing number of applications in the case of pumping machinery. Many large plants have been erected. One of the largest is an engine of 1000 h.-p. lifting 6 cubic metres (1320 gallons) of water per minute to a height of 450 m. (1476 ft.). Plunger pumps worked by electricity mostly take the form of three rams driven from a common crank-shaft, fixed upon the same bedplate as the motor. In the early installations the high speed of the motor was reduced by gearing, so as to give the crank-shaft a number of revolutions per minute suitable for pumping, but now the quick-running pumps of Riedler, Ehrhardt and Sehmer and others can be worked direct from the motor shaft running at a speed of over 300 revolutions per minute.

Fig. 224 shows Ehrhardt and Sehmer's quick running pump. The twin double-plunger pump of this firm, with a stroke of 15¾ in. (400 mm.), and a plunger diameter of 5¼ in. (132 mm.), running at 146 revolutions a minute, will raise 660 gallons of water (3 cubic metres) to a height of 1706 ft. (520 m.) in that time.

We now come to the cases in which the prime mover is placed underground. The advantage of this plan is evident, for it enables

us to dispense with most of the transmitting appliances, besides being generally more economical in first cost and more speedy in erection. The great objection is the danger of the machinery being 'drowned' by an influx of water, and so rendered useless; a mishap of this kind would involve the erection of a new pumping plant for draining the mine.

Underground prime movers are steam engines, water power engines, and petroleum engines.

The steam may be generated above or below ground; if the

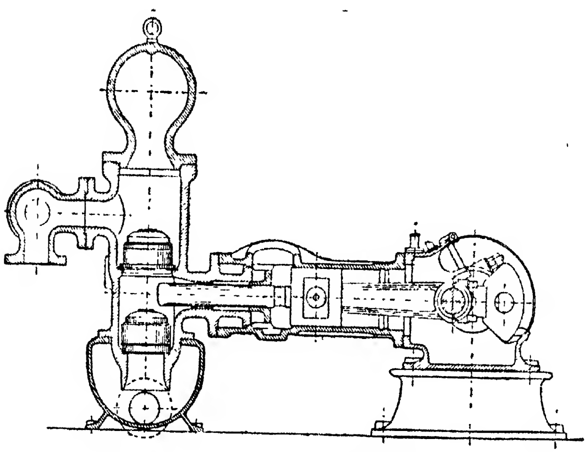


FIG 224.—Ehrhardt and Sehmer's electric 'Schleifmuhle' Express pump.

boilers are placed above ground, as is almost invariably the case, great care has to be taken in jacketing the steam pipe which comes down the shaft, in order to prevent loss of heat by radiation and the consequent unprofitable expenditure of fuel.

The steam engine is generally horizontal, and it may or may not have a fly wheel. The plunger is placed in a line with the piston rod, and forces the water up one long column of pipes. The height to which such a column can be taken is governed by the strength of the pipes, and the difficulty of making joints sufficiently tight to resist pressures measured by hundreds of pounds to the square inch. At La Louvière mine in Belgium the column is 630 yards (576 m.) high, which means a pressure at the bottom of 55·6 atmospheres, or 817 pounds to the square inch.

Figs. 225 and 226 give a general idea of one of the underground pumping engines at Mansfeld. It is a horizontal compound engine working four plungers or rams. A is the high-pressure

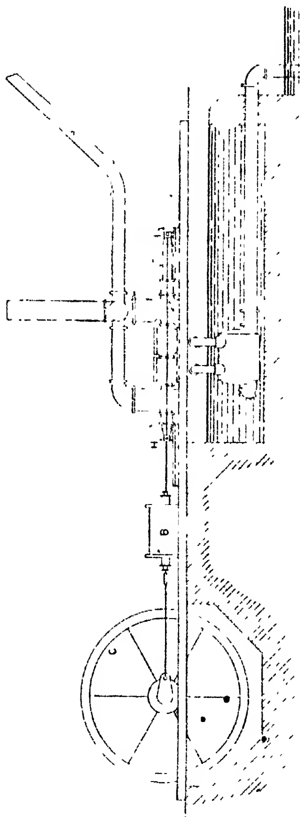


Fig. 225.—Direct-acting underground pumping engine, Mansfeld copper mines. Elevation.

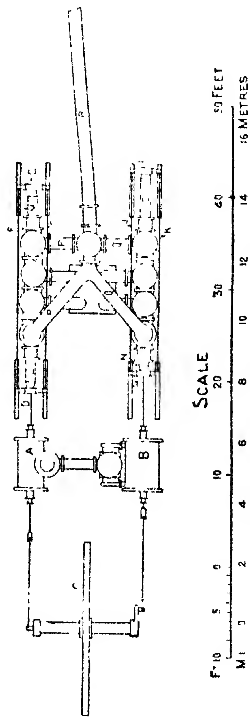


Fig. 226.—Direct-acting pump, Mansfeld copper mines. Plan.

cylinder, B the low-pressure cylinder. C is the fly-wheel, D and E are cross-heads connected by rods F and G, and similarly, H and I are cross-heads connected by the rods J and K; L M N O are

the four rams, each $9\frac{3}{4}$ in. in diameter, having the same stroke as the pistons of the engine. P P′ and Q Q′ are delivery pipes leading to a main delivery pipe R, which goes to the rising main in the shaft. When the engine is working at the rate of 30 revolutions per minute, it is calculated that it raises 1540 gallons of water per minute to a total height of 612 ft.

In addition to the pumps just described, certain special forms are occasionally employed in mines, such as the pulsometer, the centrifugal pump, and the Pohle pump. The first is a steam pump in which the steam acts directly upon the surface of the water without the intervention of a piston. It is much employed at mines and quarries for heights not exceeding 70 or 80 ft. It will pump muddy or gritty water; it occupies little space, is very portable, and is easily fixed; in fact, it may even be hung in a shaft from a chain, it requires no special attendant, and will go on working by itself as long as it is supplied with steam.

Centrifugal pumps are especially applicable when large quantities of water have to be raised to a small height, not exceeding about 80 ft. (25 m.). They are simple, have few wearing parts, and take up little room. As they have to be driven at a high speed, the axle of the pump may be coupled directly to the shaft of an electric motor. For heights exceeding 25 m., so-called high-lift centrifugal pumps are employed with two or more compartments, the second taking the water directly from the first, the third from the second, etc. Simple centrifugals may be used as pilot pumps in sinking shafts, and they can conveniently be hung from chains.

The Pohle pump is the simplest in existence. It is merely a pipe plunged into water with a jet of compressed air brought in at the bottom. As the bubbles of air ascend they carry up water with them, but their efficiency is small.

(6) Co-operative Pumping.

Owing to the sub-division of property in this country and want of appreciation of the importance of the subject, too little attention has been paid to what may be called co-operative drainage.

One successful application of this principle, however, deserves notice. The South Staffordshire Mines Drainage Commission is a corporate body constituted under several Acts of Parliament for the purpose of carrying on the drainage of mines in parts of South Staffordshire and East Worcestershire. The Commissioners have power under their Acts to levy a rate of 9d for every ton of coal, slack, and ironstone raised within a certain district, and 3d. for every ton of fireclay and limestone.

It is not merely by erecting pumping engines of the most approved and economical types at suitable centres that the Commissioners have done good work; the results of their labours in preventing surface water from finding its way down are also well worthy of record.

According to the annual report published in 1892,* $27\frac{1}{2}$ tons of water were raised for every ton of mineral extracted from the mines, and at the cost, so far as the Commissioners' engines were concerned, of 0·18 of a penny, or less than one farthing, per ton of water raised.

* *Colliery Guardian*, vol. lxiv., 1892, p. 648.

CHAPTER X.

VENTILATION.

The remarks made at the beginning of the previous chapter may to a certain extent be repeated in the case of ventilation. It often appears a small matter to supply a mine with an adequate quantity of fresh air, because Nature unaided will in some instances do all that is needed. But when we are dealing with coal seams emitting large quantities of dangerous gases, the question of ventilating the workings, often spreading over a very considerable area, assumes a totally different aspect. At the Ronchamp collieries in France, no less than 471 cubic metres of fi artments, given off for hird from metre of coa ot pumps These propo n chains. shown by the t nerely a panying squar it in at areas are as 1 to water

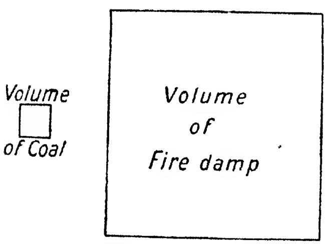


Fig. 227.—Squares indicating by their areas the proportion between the volume of the coal extracted and the volume of the fire-damp emitted at the Ronchamp collieries, France.

To dilute an harmless this quantity of inflan three million tons sent into the min want ally; in fact, the we ten- the air sent into th is nearly twelve tin rves of the coal extracte n is

This proportion is ent less a little high; nevertheless, it is no uncommon thing s of country to have such ratios as 5, 6, or 8 to 1. The impo ers of ventilation thus becomes very manifest. ion

I propose in this chapter to explain first the causes by nd mine air becomes polluted; secondly, the methods and appli

by which currents of air are produced and made to circulate through the workings; and thirdly, the mode of testing the quality of the air and measuring its quantity and pressure.

(1) Causes of the Pollution of the Air in Mines.

The atmosphere of mines is subject to various influences which are constantly rendering it less fit for supporting life; not only do noxious gases escape from the rocks into the underground excavations, but the very agents themselves employed in the execution of the work pollute the air continually. We therefore have to deal with natural and with artificial causes of pollution.

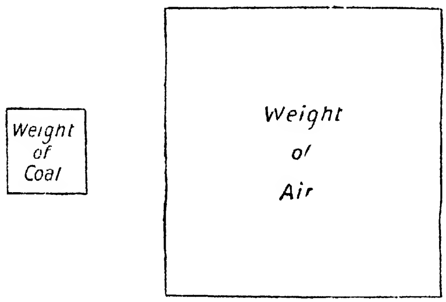


FIG. 228.—Squares indicating by their areas the proportion between the weight of the coal extracted from the Ronchamp collieries and the weight of the air sent into them.

The two most important gases which issue from the rocks and trouble the miner are methane and carbonic acid; in addition there may occasionally be sulphuretted hydrogen, vapour of mercury, and volatile hydrocarbons.

Methane, CH_4, is a colourless, inodorous gas with a specific gravity of 0·56 (air = 1). It has no direct poisonous properties; but if present in sufficient quantity, it so dilutes the proportion of oxygen that the atmosphere is no longer capable of supporting human life, and death ensues from suffocation. Methane is inflammable, and it forms explosive mixtures with air; the explosive force of the mixture is greatest with 9·38 per cent. of the gas.

It is the main constituent of 'fire-damp,' the name given to

inflammable gas found in mines. Coal is a great storehouse of fire-damp, which exists imprisoned in the pores of the mineral in a highly compressed or possibly liquid state, and escapes gradually, sometimes with a hissing noise. Occasionally large accumulations of fire-damp are met with by the miner, and the emissions may go on continuously for years. This is in no way surprising, if we reflect upon the vast quantities of gas now shut up in various rocks, which are set free by mere boreholes from the surface in the United States and even in Sussex.

The presence of fire-damp is by no means confined to coal mines, as some might suppose; in this country it is found in small quantities in the stratified ironstone of the Cleveland district, and also in the Cheshire salt mines. Mill Close in Derbyshire, Holway Consols in Flintshire, and the Van in Montgomeryshire, may be cited as examples of lead mines where explosions of fire-damp have happened; indeed a portion of the first-named mine is still worked with safety lamps.

Turning to the Continent, it is not surprising that large quantities of fire-damp are met with in sinking oil wells in Roumania, and in the workings for ozokerite in Galicia. There are probably few, if any, mines more fiery than the ozokerite pits of Boryslaw. Explosions have often happened, and the mines have to be worked with safety lamps. However, it is likely that both here and in the oil regions generally the inflammability of the atmosphere is due not only to marsh gas, but also to the vapour of volatile hydrocarbons given off by the crude petroleum, which may be seen on the floor of the workings.

The sulphur rock of Sicily emits fire-damp very frequently, and the official list of disastrous explosions shows that it is an enemy not to be despised by the miner. The gas fills cavities existing in the sulphur seams, and also comes out of the bituminous shale of the partings; it is called *antimonio* by the men.

Carbonic acid, CO_2, is a colourless, inodorous gas with a slightly pungent effect on the tongue. Its specific gravity is 1·5 (air = 1). It is not combustible, and it will not support combustion. Like methane, it occurs under pressure in the pores of rocks, and it may escape in very considerable quantities. Huge emissions have been observed in workings for coal, sulphur, and metallic ores. At the Rochebelle* collieries in France, there have been sudden outbursts causing loss of life in several cases.

Pontgibaud lead mine in Central France is likewise remark-

* Lange, "Les dégagements d'acide carbonique aux mines de Rochebelle," *Bull. Soc. Ind. Min.*, vol. vi., 3me série, 1892.

able for formidabl[illegible]es of carbonic acid gas; they probably represent the last dying throes of the volcanic activity which once characterised this region. The quantity of gas was sometimes great enough to partly fill the levels, where, owing to its high specific gravity, it lay on the floor to a depth of a foot or more, whilst the miners felt little inconvenience, as they were breathing a stratum of fairly pure air near the roof.

Sulphuretted hydrogen, H_2S, is a colourless gas with the easily recognisable odour of rotten eggs. Its specific gravity is 1·19 (air=1), but, unlike methane and carbonic acid, it has decidedly toxic properties. Its presence has been noticed in lead mines in this country, and it is of frequent occurrence in the sulphur mines of Sicily, where the water is sometimes saturated with it.

Small quantities of mercurial vapour are stated to be found in quicksilver mines and to be the reason of their unhealthiness; but one feels inclined to suggest that constant contact with native mercury or cinnabar, inhaling the dust of the mineral, and allowing some to enter the stomach from eating with dirty hands, may possibly account for all the symptoms of poisoning.

As already stated, the pollution of the air is not due solely to gases introduced naturally from the surrounding rocks; several artificial causes combine to render the atmosphere of the mine unfit for life, and among them may be mentioned the following:—

(*a*) Respiration of the persons and animals in the pit; exhalations from their skin, and emanations from excrement left underground.
(*b*) Combustion of the lamps and candles used for lighting the working places.
(*c*) Explosions of fire-damp and coal dust.
(*d*) Underground fires.
(*e*) Absorption of oxygen by coal, pyrites, and other minerals.
(*f*) Decay of timber.
(*g*) Explosion of gunpowder, dynamite, etc.
(*h*) Dust.
(*i*) Air delivered by compressors, occasionally.

(*a*) and (*b*) Dr Angus Smith reckons that two men working eight hours, and using ½ lb. of candles and 12 oz. of gunpowder, produce 25·392 cub. ft. of carbonic acid at 70° F.—viz., 10·32 by breathing, 12·276 by candles, and 2·796 by gunpowder.

It is considered by medical authorities that the injurious effects of breathing an atmosphere polluted by the products of respiration are due more to the organic matter than to the carbonic acid it contains. The quantity of carbonic acid produced by breathing serves, however, as an index of the amount of organic pollution.

(*c*) When carbon or a carbon compound is burnt with an insufficient supply of oxygen, one of the resultant gases is carbonic oxide. This is a colourless, inodorous gas with a specific gravity of 0·97. Its poisonous properties are very marked. An atmosphere containing only 0·07 per cent. produces headache and giddiness if breathed for some hours; if the quantity is increased to 1 per cent., a person falls down unconscious at once, and death will ensue unless he is speedily rescued.

The name 'after-damp' is given to the gases resulting from an explosion of fire-damp or coal dust; these gases are mainly carbonic acid, carbonic oxide, and nitrogen mixed in various proportions.

The miner owes a debt of gratitude to Dr Haldane,* who was the first to point out that the majority of the victims of explosions in coal mines die from suffocation by carbonic oxide and not from the violence of the explosion. This fact has an important bearing upon the best means of rescuing possible survivors.

(*d*) Underground fires due to burning timber or burning coal are other sources of carbonic oxide in mines, and as the gas is so exceedingly poisonous, a comparatively small fire may have very disastrous effects. Where iron pyrites is present, as is so often the case in coal, some sulphurous acid is produced, and in the exceptional case of workings for native sulphur the quantity generated is sometimes quite large enough to cause death.

At one of the recent fires at the Broken Hill mines, N.S.W., it was noticed that pyroligneous ether resulted from the dry distillation of some of the timber, and produced intoxicating effects upon the men who happened to be exposed to the fumes.

(*e*) The so-called 'black damp' of mines † is air deficient in oxygen and containing a very decided excess of carbonic acid. It

* Haldane, "Report to the Secretary of State for the Home Department on the Causes of Death in Colliery Explosions and Underground Fires, with special reference to the Explosions at Tylorstown, Brancepeth, and Micklefield," London, 1896 (c. 8112).

† Haldane and Atkinson, "Investigations on the Composition, Occurrence and Properties of Black-damp," *Proc. Fed. Inst. M.E.*, vol. viii, 1894-95, p. 549.

is due to the prolonged contact of air with coal or other organic matter in the rocks. Where the ventilation is sluggish, the absorption of oxygen by coal, pyrites, or ferruginous minerals passing to a higher state of oxidation, is often very marked.

(*f*) The rapidity with which timber rots underground in certain circumstances has already been mentioned; the practice of leaving the useless decaying timber to infect the new pieces that are put in, sometimes turns a level into a hot-bed of putrescent matter, offensive to the smell, and injurious to the health of the men. Steel supports should be welcomed, if only for ridding mines of one source of pollution of the atmosphere. Under certain conditions decaying timber will generate methane, and fire-damp produced in this manner has on various occasions been the cause of explosions.

(*g*) Some explosives give both gases and solid residues when they are fired. In the case of gunpowder, the smoke is made up of fine particles of carbonate and sulphide of potassium with some sulphur, whilst the explosive force has been due to the formation of a number of invisible gases, especially carbonic acid, carbonic oxide, and nitrogen, with sulphuretted hydrogen, marsh gas, and hydrogen.

Nitro-cotton should produce nothing by its explosion but carbonic acid, carbonic oxide, steam, hydrogen, and nitrogen; and nitroglycerine only carbonic acid, steam, nitrogen, and oxygen. But when imperfectly detonated, the resultant gases are more noxious; both explosives generate a large proportion of nitric oxide, and carbonic oxide is liberated in considerable quantity.

(*h*) One of the worst impurities in mine air is dust. It arises from various causes; much is produced in boring holes for blasting unless special means are adopted to prevent it. Some is sure to be formed when pieces of stone are knocked against each other in the process of excavation or shovelling, and, in the case of a tender mineral like coal, haulage is largely responsible for the evil. Pieces tumble off the waggons or drop through chinks and are gradually crushed up by the traffic into an impalpable powder so fine that it will float in the air.

A dust-laden atmosphere is harmful in two ways: particles of stone choke and irritate the lung passages and so cause disease, and air mixed with some kinds of coal dust will cause explosions.

(*i*) Compressed air used for working rock drills, &c., sometimes contains carbonic oxide and other gases, which are generated by the heat due to compression, either from the lubricant used in the cylinder, or from coal dust or even from the washers of the air-pipes.

(2) Methods of producing Air Currents.

Two systems of ventilation are employed in mines—natural and artificial. Under the former, currents set up by natural differences of temperature change the air of the workings; under the second, artificial means are employed to bring about the same result.

The principle upon which natural ventilation depends is very easily understood. The temperature of the earth increases at the rate of 1° F. for every 60 ft of depth, and this natural heat is the mainspring in creating air currents. Suppose a very simple case, two shafts A B, C D (fig. 229), connected by a horizontal level B D. The air in the shafts and level, warmed by its contact with the sides of these underground passages, gradually assumes their temperature, which will be usually higher or lower than that of the external atmosphere; the problem is simply that of two communicating vases. At the point D we have the pressure due to the weight of the column C D + the weight of the atmosphere at C; at B the pressure due to the smaller column A B + the weight of the atmosphere at A.

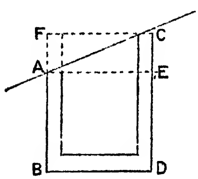


FIG. 229.—Diagram explaining the principle of natural ventilation.

Draw the horizontal lines C F and A E, and prolong the line of the shaft A B upwards by the dotted lines. The pressure of the atmosphere at F and C is the same, and therefore any difference of pressure at B and D depends upon the relative weights of the columns F B and C D; but A B is equal to E D,* so that the real difference depends upon the weights of the two columns of air—F A outside the mine, and C E inside the mine. In this country the external atmosphere in summer is often hotter than that of the mine; therefore the column C E will be heavier than the column F A. The column C D will overcome the resistance presented to it by the column F B, and create a natural current going in the direction C D B A. In winter the conditions are reversed. The cold external column F A is heavier than the comparatively warm internal column C E, and the weight of the entire column F B will be greater

* This is only approximately the case, for E D lies, on the whole, deeper than A B from the surface, and therefore, in general, E D should be a little the warmer.

than that of the [illegible] CD. The result is that the weight of the column F B will cause motion in the direction A B D C.

In any one of these cases, the greater the difference in temperature, the greater will be the velocity of the ventilating current. In winter the ventilation will be more active than in the summer, because there will be more difference between the outside and inside temperatures; and, furthermore, though there are differences between the day temperature and the night temperature, still the tendency is always to produce a current in the same direction. In summer the nights may be cold though the days are hot, and therefore the difference in temperature between the air of the mine and that of the surface may be acting in two opposite ways according to the period of the day or night. A shaft which is drawing up, or is an 'upcast,' during the heat of the day, may have a descending current, or be a 'downcast,' in the cool hours of the night, and practically have no current at all, while the outside and inside temperatures are alike.

There is not only this objection to natural ventilation, that it may vary in direction during the course of twenty-four hours, but the still greater objection that at certain seasons of the year it may be *nil*, because there is no difference in temperature between the outside and inside air to make one column heavier than the other.

The creation of a natural air current is not due solely to the difference of temperature caused by the natural warmth of the rocks. The heat engendered by the respiration of the men and animals, by the combustion of the lamps or candles, and, lastly, by the explosives, is also a factor in making the air of the mine warmer than that of the surface, and so setting up a current.

I take this opportunity of correcting the common statement that carbonic acid invariably collects in the lowest part of the workings. This is correct only in cases where the gas is issuing forth from rocks and sinks down like water. Where it is produced by respiration, candles, lamps, or explosives, it is diffused through a warm atmosphere, ascends with it, and does not separate from the other gases. The consequence is that a 'rise' may be found badly ventilated, although the air i[illegible] he level below is fresh and pure.

As already pointed out, natural ventilation is often weak or inconstant, and therefore cannot be relied upon for furnishing an adequate supply of air; it then becomes necessary to resort to artificial means for producing air currents.

Artificial ventilation is effected by heat or mechanically. By placing a furnace at the bottom of a shaft, the miner warms the

column of air which it contains, and so renders it lighter than a similar column in an adjacent shaft with which the first is in communication. Again, we have a case of two communicating vases: the weight of the heavier column of cool air overcomes that of the lighter column of warm air; a current is produced, and continues so long as there is fire to do the heating. Let A B and C D represent two shafts, and suppose a furnace to be placed at D. The warm column C D will be lighter than the colder column A B, and a current will be created, descending the 'downcast' shaft A B, passing from B to D, and ascending the 'upcast' C D. In actual practice the current does not go direct from B to D, but is diverted by doors and stoppings so as to sweep through the roadways and working faces before ascending the upcast.

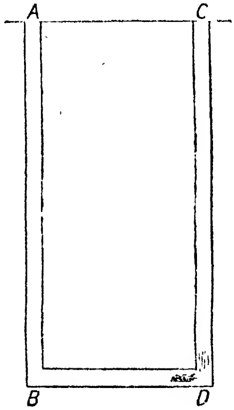


FIG. 230.—Diagram explaining the principle of furnace ventilation.

In small workings a little fire lit at or near the bottom of the upcast shaft, or contained in an iron vessel suspended in the pit, is sufficient for the purpose. From petty beginnings of this kind has developed the large underground furnace, which in its turn is gradually being ousted by mechanical appliances. Of these latter by far the most important is the centrifugal fan.

The fan is characterised by the fact that the current is produced by blades or vanes fixed to a revolving shaft. The air lying between them is whirled round and round, and flies off tangentially at the tips, like a stone from a sling. The space previously occupied by this air is at once filled by supplies coming in at the centre, and the process goes on continually. The centrifugal ventilators or fans are generally used as exhausters—that is to say, they are arranged so as to suck air out of the mine, instead of forcing it in.

Five types of fans very largely used at the present day are, in alphabetical order, the following:—Capell, Guibal, Rateau, Schiele, and Waddle.

The Capell fan (fig. 231) consists of two concentric cylindrical chambers, each provided with six curved vanes or blades, the

convex sides of [illegible] are turned in the direction of the rotation. The cylindrical shell or drum b, between the two sets of vanes, contains openings or port-holes $d\,d$, allowing the air to pass from the inner to the outer chambers. There is one such chamber between every two vanes. The air contained between any two of the inner vanes c, is thrown out by centrifugal force when the fan revolves, and passes at a high velocity into the corresponding outer chamber. Here it is supposed to strike against the concave vane, and give back to it the greater part of the impulse received from the inner chamber. The advantage claimed for this fan is that it discharges the air with the least possible velocity, and therefore even when driven at a high rate of speed can do a large amount of work in spite of its comparatively small diameter.

The Guibal fan (fig. 232) is a fan with eight or ten straight blades, which are not set radially. An important peculiarity,

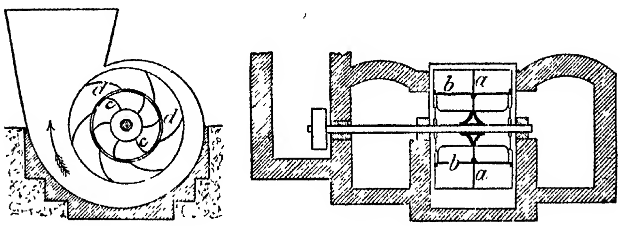


FIG. 231.—Capell ventilating fan.

introduced by Guibal, and since copied by others, is the expanding stack or chimney, which gradually lessens the velocity of the air as it travels towards the point of discharge into the outer atmosphere, and the sliding shutter a. The shutter enables the opening of the fan casing into the expanding chimney to be regulated at pleasure.

The Rateau fan (fig. 233) draws in the air on one side only. It consists of from 18 to 24 curved blades of steel plate attached to a horizontal axle. These blades in revolving cause the air to be drawn in at the centre, and then expelled at the periphery into a volute-shaped diffusor, which gradually increases in size and ends in an upright chimney. The central part, shown open in the figure in order to display the blades, is closed in by a huge steel pipe which connects the fan with the fan drift.

The Schiele fan is somewhat like the Guibal. It has the same expanding chimney, but the blades are curved and the casing is

not close (fig. 234); besides, the width of the blades is not the

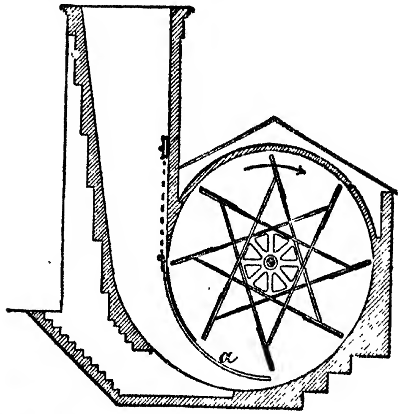


FIG. 232.—Guibal ventilating fan.

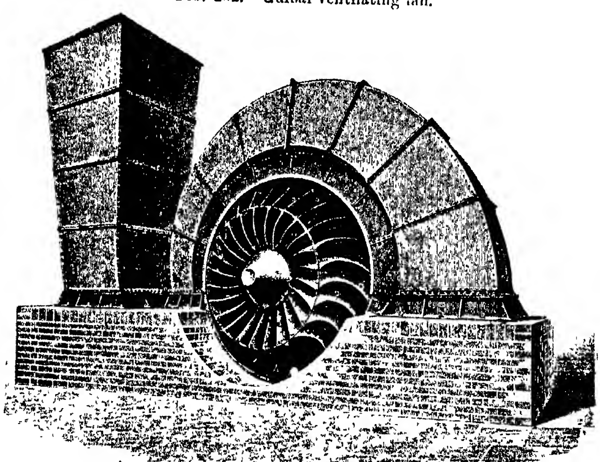


FIG. 233.—Rateau ventilating fan.

same throughout. The blade is widest in the middle, and then

it decreases both towards the centre of the fan and towards the tips. It is small as compared with the Guibal.

The Waddle fan differs from those just described by running open—that is to say, it is not enclosed in any external casing (fig 235). It is a very flat hollow truncated cone, with the base closed and a central opening on the other side. The air passes in at the centre and is discharged at the circumference. These fans are made with a diameter of 30 to 45 ft. A recent improvement is the addition of a divergent outlet; the velocity of the air leaving the fan is thus lowered, and less power is required for driving. This fan, like the Guibal, is a

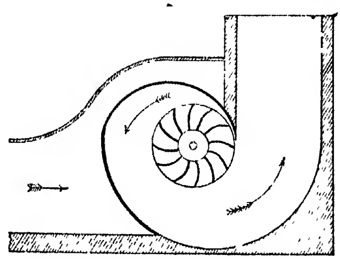


FIG. 234.—Schiele ventilating fan.

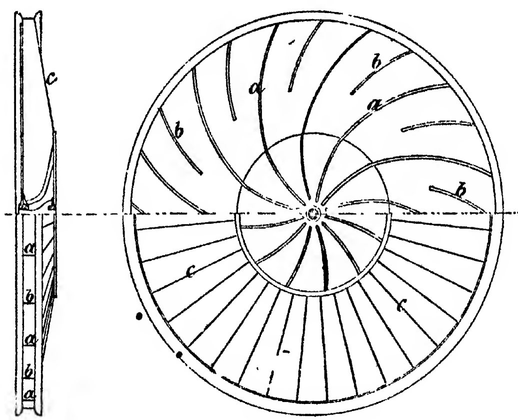


FIG. 235.—Waddle ventilating fan.

slow-running one, which can be driven directly from the engine without the aid of belts or gearing.

Some comparative tests made in England a few years ago* showed that the Guibal fan is a more efficient ventilator than the Capell, the Schiele, or the Waddle; whilst a trial in Belgium lately proved the superiority of the Rateau over the Guibal.

A description of mechanical appliances for producing air currents would not be complete if it stopped at fans; other means, though of secondary importance, have to be mentioned.

Where compressed air is employed, the exhaust from the machine may do good service in driving out foul gases generated in the workings, and there is the further advantage that, after blasting, a powerful stream of air can be turned on for a short time so as to sweep out the noxious fumes completely. A jet of air or water under pressure turned into a large pipe drives its contents forwards, and so creates an exhaust from behind which may be employed for sucking out the bad air from an 'end' or other advanced working place. It is likewise possible to reverse the action and drive in fresh air instead of sucking out the foul.

The Hartz blower (*duck machine*, Cornwall) is a large wooden air-pump of simple construction, which is attached to the main rod in a pumping shaft, and provided with pipes proceeding into the workings; it can be made to act as a blower or an exhauster.

The mere production of an air current, descending one shaft of a mine and ascending the other, is not all that is required. If left to itself, the air on reaching the bottom of the 'downcast' pit would rush by the nearest road to the bottom of the 'upcast' and leave the advanced workings, a mile or more away it may be, entirely unventilated. It therefore becomes necessary to force the current to travel along certain definite paths in order that it may scour through all parts of the mine. The means employed for distributing the current are stoppings, doors, brattice cloth (*sheets*), and crossings. If a level by which the air current could take a short cut to the upcast is no longer required, it should be closed permanently by putting in a stopping—*i. e.*, building up a strong wall of brickwork. On the other hand, if traffic has to be carried along the roadway, the short circuiting of the air is prevented by a door, which is hung so that it will close of itself when opened; it is also arranged so that the pressure of the air current shall tend to keep it shut. To prevent unnecessary leakage of the air current, two doors may be put up instead of one, the second not being opened until the first is shut. Where such leakage is quite unimportant, a piece of strong canvas (*brattice cloth, sheet*) is hung from the roof and lifted up when a person has

* M. Walton Brown, "Mechanical Ventilators," *Trans. Inst. M.E.*, vol. xvii., 1900, p. 505.

to pass along. The current of foul air returning from the working face may occasionally have to cross the path of the ingoing stream of fresh air; here it becomes necessary to construct a hollow bridge or crossing—in other words, one current is carried over the other in a passage cut through the strata and suitably lined with timber or brickwork.

If the mine is large, it is unwise to make the entire current pass through the whole of the workings, because there would be an unnecessary waste of ventilating power in overcoming the friction between the air and the sides of the passages. Consequently the main current is sub-divided or 'split' into secondary currents, each of which ventilates one portion of the workings; the secondary currents are then brought together near the upcast and ascend in one big stream.

(3) Testing the Air of Mines.

Mine air is tested as to quality, quantity, and pressure.

A knowledge of the quality of the air is desirable for two reasons: it may contain gases capable of causing accidents by explosion or suffocation, or it may be polluted by gaseous or other impurities likely to injure the health of the men who have to breathe it.

In this country the testing as to quality is mainly confined to a search for one dangerous ingredient—viz., inflammable gas—and the method of search is almost invariably the same. The miner draws down the wick of his safety lamp until the yellow flame almost disappears, and then holds the lamp near the roof, for it is there, if anywhere, that the light methane will collect. If the gas is present in sufficient quantity, its combustion produces a pale blue 'cap,' halo or aureola, around the little flame, and the greater the proportion of fire-damp, the higher the cap. Experienced observers do not profess to be able to detect the presence of gas in this manner if the percentage falls below 2½. A lamp fed with benzine in place of oil gives an indication even with 1 per cent., and, as pointed out originally by Pieler [illegible] one case and Le Chatelier in the other, the hot non-luminous flames of alcohol and hydrogen enable still smaller quantities of fire-damp to be recognised. Chesneau's lamp, largely employed in France, is an improved Pieler lamp, with a little nitrate of copper and dichloride of ethylene dissolved in the alcohol; it will detect ¼ per cent. of inflammable gas in air. Stokes' lamp is an ordinary safety lamp with a small detachable alcohol lamp; the official is thus relieved

from the necessity of carrying two large lamps, one for lighting his path and the other for testing

Clowes follows Le Chatelier by using a hydrogen flame, but adapts a detachable reservoir of hydrogen to an ordinary safety lamp in a manner which enables either flame to be used at pleasure.

Beard & Mackie attach above the wick tube a frame like a miniature ladder with horizontal cross-bars made of platinum wire. The greater the amount of gas present, the hotter and longer will be the flame; and the percentage of gas is gauged by the height to which the cross bars are heated to redness.

Le Chatelier's method of determining the amount of fire-damp in mine air by measuring the limits of inflammability of gaseous mixtures is one of great delicacy, for it gives results which are comparable in exactness with those of a chemical analysis. But the determinations have to be made at the surface, and consequently samples of the air have to be brought up in bottles from the mine. Le Chatelier's method is in regular daily use at certain French collieries; and his burette is a far simpler, cheaper, and less cumbersome piece of apparatus than that brought out by Shaw, though the latter may claim the credit of having been the first to point out the principle upon which the determinations are based.

The only other mode of testing air commonly employed at mines consists in observing the effect of the air upon the flame of the ordinary miner's candle. It is of use in some cases. If carbonic acid gas is issuing from the rocks, it settles down to the bottom of the excavation in virtue of its specific gravity, and men have frequently been asphyxiated by descending into shafts or wells in which the gas had accumulated without their knowledge. Where danger of this kind may be apprehended—for instance, in mines liable to emissions of carbonic acid, or in the case of old workings that have not been recently entered—a lighted candle should certainly be lowered before letting a man go down. If the candle is found to burn brightly, it is generally concluded that there will be no danger in making the descent; if it goes out, it is evident that the air is unfit to support combustion and human life; if it burns dimly, there is need for the greatest caution.

Dr Angus Smith considers that the candle test affords no distinct sign that the air is bad, until the impurities have reached an amount beyond the maximum which is consistent with good ventilation. Thus the candle affords no indication of the presence of $\frac{1}{4}$ per cent. of carbonic acid; if the percentage

is greater than this he says that men should not be allowed to work, and, to use his own words, "it follows therefore that the candle as used is only valuable when the air is so bad that no one should be allowed to remain in it."

Small proportions of carbonic acid, which are wholly unrecognisable by the candle test, can readily be detected and easily measured by chemical methods which are quite within the powers of an ordinary mine agent, but want of space forbids my dealing with them here.

The quantity of air passing through any given passage can be calculated by measuring its sectional area and ascertaining the speed of the current by means of an anemometer.

The commonest type of anemometer (fig. 236) is an instrument provided with vanes *a a* like those of a windmill; by the aid of very simple gearing, the number of revolutions of the spindle carrying the vanes is recorded on suitable dials like those of a gas meter, and the velocity of the current is deduced from the number of revolutions in a given time.

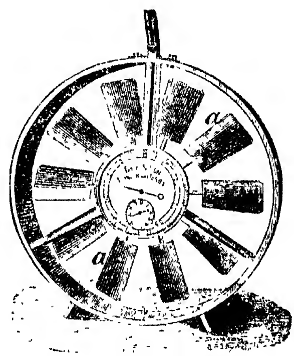


Fig. 236.—Biram's anemometer.

The area of the passage in square feet multiplied by the velocity in feet per minute gives the number of cubic feet per minute.

A mere knowledge of the volume of air passed through the workings does not suffice; in addition, it is necessary to determine the amount of rarefaction produced by the ventilating machine—in other words, the difference between the pressure of the air in the mines and that of the external atmosphere. The instrument employed for this purpose is the manometer or water-gauge. It is a glass tube bent in the form of a U, partly filled with water; one leg is in communication with the outer atmosphere, and the other with that of the mine. It is usually placed in the engine house of the fan, and a pipe is carried from it into the fan drift. The suction of the fan causes the pressure of air in the mine to be less than that of the external atmosphere, and the diminution of pressure is indicated by the difference in the heights of the two columns of water in the U-tube. This differ-

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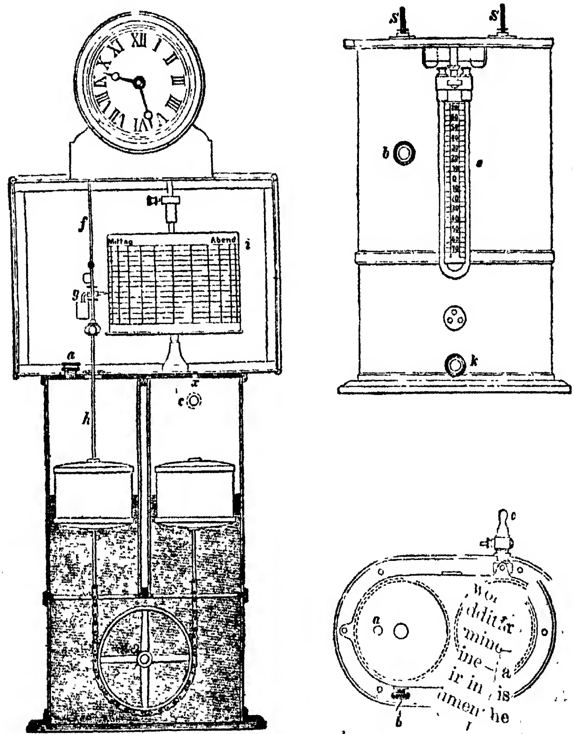
ence in pressure is measured by a scale of inches, which is moved up and down by a screw, until the zero corresponds with the level of the water in the free limb.



FIGS. 237, 238, 239.—Ochwadt's self-recording water-gauge, made by Pintsch. Front elevation, rear elevation, and plan of the cylinders.

In Prussia it is necessary to keep a record of the manometrical depression ('water-gauge') produced by the fan. A self-recording water-gauge largely used is the one invented by Ochwadt and constructed by Pintsch (figs. 237, 238, and 239).

It consists of two cylindrical reservoirs partly full of water and connected at the bottom. One reservoir is connected with the fan drift, and the other with the external atmosphere.

In each cylinder there is a float, and the two floats are connected by a piece of chain running round a pulley. The rod *h* attached to one of the floats carries a writing pen *g*, which is kept in a proper position for work by the rod *f*; *i* is a cylinder driven by the clock shown on the upper part of the instrument, and the sheet of paper for the diagram is fixed upon it by two india-rubber bands. The horizontal lines denote differences of pressure, whilst the vertical lines indicate the successive hours of the day. In order to start the instrument, water is poured in through a hole *a*, until it runs out at *b* (figs. 238 and 239). These holes are then closed up by screws, and the nipple *c* is connected by means of a piece of flexible pipe with the mine; *e* is an ordinary water-gauge made of a bent glass tube, which serves to check the indications of the main apparatus While at work the hole *x* (fig. 237) must be closed by a screw. The screw *k* closes a hole which may be used for completely emptying the apparatus of its water. The two rods *s* and *s* simply serve for the purpose of carrying the apparatus about when necessary. It is evident that any difference of pressure between the air in the two cylinders will be indicated by a difference of level between the two surfaces of water. When *c* is put into communication with the mine, the water will rise in that side and fall in the other, and the variations in pressure will be duly recorded by marks on the diagram paper. The resulting curve will be a record of the state of the water-gauge for 24 hours. The instrument shown in fig. 237 supplies the record for one day; a similar instrument is made giving a record for 7 days.

CHAPTER XI.

LIGHTING.

In underground workings artificial light is a necessity at all times, and in quarries it is required when the work is carried on at night.

The means of illumination employed are as follows:—(1) reflected daylight; (2) candles; (3) torches; (4) ordinary open lamps; (5) ordinary safety lamps; (6) electric lamps; (7) miscellaneous lamps.

(1) Reflected Daylight.

For sinking oil-wells in Japan reflected daylight is used. A piece of translucent oil paper about 5 ft. by $3\frac{1}{2}$ ft. is suspended over the well at an angle of 45°, and throws light down the pit, which may be dug to a depth of 600 to 900 ft.

In driving the Bell tunnel at the New Idria quicksilver mine in California, there was a disastrous explosion from inflammable gas, and after that the tunnel was illuminated by sunlight reflected from a mirror placed at the mouth of the drift.

(2) Candles.

The candles used by miners are very frequently the so-called 'dips'—that is to say, they are made by dipping a wick into molten tallow and allowing it to take up a coat of grease; the process is repeated several times, until by addition of several coats the thickness of tallow is sufficient. The wick is made of cotton, or of cotton and linen.

As a rule the British miner holds his candle in a lump of clay, which forms a very convenient support, as it can be readily stuck up at any point where it is wanted. It can also be stuck upon the hat when the miner wants to climb a ladder or a chain.

The tallow candle has the disadvantage of guttering in a

draught and of course a good deal of smoke, which is bad if the working place is at all close. Paraffin, stearine, and 'composite' candles are often used in place of the common dip; they do not stand a strong draught or drops of water so well as the latter, but they give less smoke and do not gutter so much.

In the United States and the Colonies a metal candle-holder is very generally employed; and for the official who has to make notes underground, it is certainly more convenient than the usual lump of clay, as with the latter it is difficult to keep the note-book clean.

(3) Torches.

Torches are seen in a few exceptional instances. Large underground chambers may be lit up for a short time, in order to examine the roof, by burning a bundle of wood shavings soaked with naphtha or petroleum.

(4) Ordinary Open Lamps.

Ordinary open lamps vary very much in shape and size. The Sicilian miner has a lamp of the simplest construction imaginable; it is a mere open cup of unglazed pottery about 2 in. in diameter and an inch deep, with a little lip for holding a cotton wick, which lies loosely in the olive oil used as an illuminant. It is ruder than many of the lamps found at Pompeii, which in shape somewhat resemble the iron lamps employed in the Hartz. The latter are provided with a hook, by which they can be held between the thumb and forefinger when climbing ladders; the hook has a sharp point which the miner can stick into a timber prop or a crevice in the rock while at work. The body of the lamp is closed, it has a tube for the cotton wick and a hole with a screw-plug through which the supply of oil can be replenished. A pricker for trimming the wick is attached by a light chain. A smaller but similar lamp is met with in France, Northern Italy, and parts of Spain: the body is lenticular, and is suspended by a long hook.

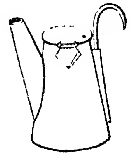


FIG. 240.—Miner's oil lamp.

In Scotland and in some parts of the United States a small but serviceable tin lamp, of the shape shown in fig. 240, is very common. It can be hooked on to the rock, or on to the hat when climbing the ladders. Olive oil or rape oil is burnt in the lamps just described, and the miner carries a supply in a little flask.

The so-called 'torch lamps' of the Wells Company are seen in quarries at night. A strong cast-iron reservoir has a beak or spout with a large cotton wick, and is supplied with petroleum. It gives a strong but smoky flame.

Lamps have the advantage of being cheaper and cleaner than tallow candles; but the latter do not seem likely to be displaced in English and Welsh ore mines, though the Scotch lead miners prefer the former.

(5) Ordinary Safety Lamps.

By 'safety lamp' is meant a lamp which has its flame so protected that it will not ignite fire-damp contained in the surrounding atmosphere.

The construction of the ordinary safety lamp is based upon the fact that gauze of a certain mesh, made with wire of a certain gauge, is capable of cooling burning gases to a point below that at which combustion will take place; in other words, it will prevent the passage of flame. Therefore, when a lamp enclosed in a suitable cylinder of this gauze is placed in an atmosphere containing fire-damp, the inflammable gas inside the envelope will burn without igniting that which is outside.

The ordinary Davy lamp (fig. 241)* consists of a brass oil vessel *b*, on to which is screwed a cylinder of wire gauze *a*, about $1\frac{1}{2}$ in. in diameter and $4\frac{1}{2}$ to $5\frac{1}{2}$ in. high. The cylinder is further closed at the top by a cap of wire gauze *e*, which overlaps the main gauze for a distance of 1 in. to $1\frac{1}{2}$ in. In the centre of the oil-vessel is a round tube containing a cotton wick, which can be trimmed from the outside by a piece of wire *f* passing up through the bottom. The gauze used has 28 holes or meshes per linear in., or, in other words, 784 per sq in. Speaking roughly, the holes are $\frac{1}{50}$ in. sq. Three rods *c*, attached below to a ring screwed on to the oil-vessel and above to a plate, protect the gauze to a certain extent. The lamp is carried by a strong wire ring fastened to the top plate *d*. Rape, colza, or seal oil, alone or with the addition of petroleum, are used as illuminants.

The Davy lamp has several defects: in the first place it gives very little light; and, secondly, it will fire an explosive mixture if the velocity of the current exceeds 6 ft. a second.

In the Clanny lamp (fig. 242) the flame is surrounded by a cylinder of glass *a*; the air which feeds the flame comes in through

* The materials used in constructing the lamps are indicated thus :—

Glass *Brass* *Thin Sheet Metal* *Gauze*

the gauze just above the glass, descends along its inner face and goes to the wick, whilst the products of combustion pass up the centre. Nothing separates the descending current from the ascending one, and consequently the oil, from want of a direct supply of fresh air, does not always burn so brightly as it does in a lamp fed from under the gauze; but the light is far better than that of a Davy lamp. In a current, however, having a velocity of more than 6 ft. in a second, it behaves like the Davy, and ignites an explosive mixture.

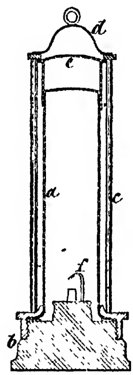


FIG. 241.—Davy lamp.

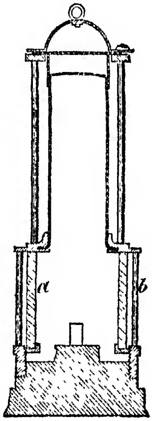


FIG. 242.—Clanny lamp

The Muescler lamp (fig. 243) may be described as a Clanny lamp with a chimney *a* fixed above the flame, and attached at the level of the top of the glass to a diaphragm or horizontal partition or wire gauze *b*. The path taken by the air is shown by the arrows. The fact of the inward current of fresh air being kept separate from the outward current of foul air assists the illuminating power of the lamp.

The Marsaut lamp (fig. 244) is of the same type as the Clanny, that is to say, it has a glass cylinder with the air entering above it, and no chimney; but it has extra safety afforded by a second or even a third gauze, and a bonnet or shield of sheet iron. These additions enable it to resist currents of 2000 ft. per minute; other advantages are an illuminating power of about two-thirds of a

tandard candle, simplicity and strength, for the gauze is protected y the shield from accidental blows of a pick or other sources of njury.

The Wolf lamp (figs. 245 and 246), very largely used on the Continent, is fed with benzoline contained in a reservoir full of otton-wool. Benzoline gives a clear flame, the brilliancy of hich is more lasting than that of a flame supplied with vegetable il, as the wick is not clogged so rapidly. The air is taken in elow the glass. An interesting feature of the Wolf lamp is the

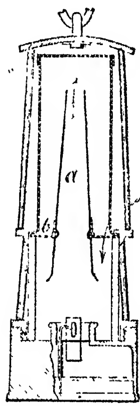


FIG. 243.—Mueseler lamp.

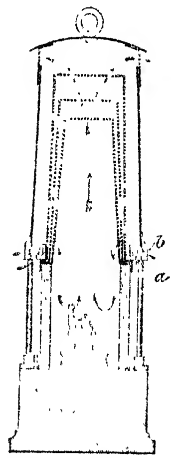


FIG. 244.—Marsaut lamp.

ingenious device for relighting it without removing the glass, so the miner is no longer tempted to break the rules and open his lamp, if by accident it goes out. The lamp has two gauzes and a corrugated shield.

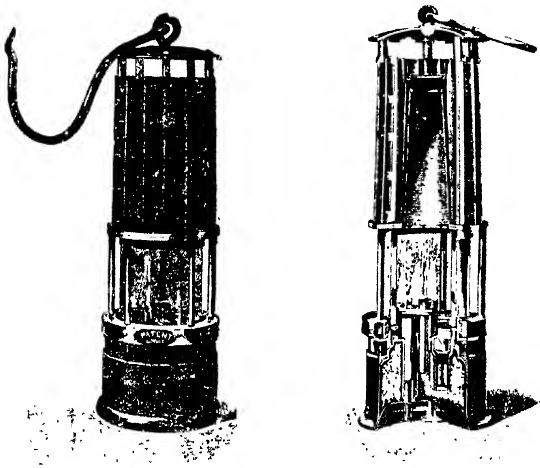
In order to prevent careless and imprudent men from risking their lives and those of their comrades by opening their lamps, it is necessary to lock them securely before they are taken into the workings. Various devices have been proposed for the purpose.

A common and satisfactory fastening is the lead rivet, which is placed through two holes, one in the brass ring holding the glass and the other in the oil vessel; it is then firmly squeezed with a pair of nippers and thus impressed with a mark, which can be

changed from day to day if necessary. The lamp cannot be opened without cutting the rivet, so any tampering with it on the part of the miner would instantly be detected at the end of the shift. Some mine owners prefer Wolf's magnetic lock, which requires a powerful electro-magnet to pull back a bolt before the top can be unscrewed.

(6) Electric Lamps.

Both arc lamps and glow lamps have their special spheres



FIGS. 245 and 246.—Wolf lamp. Wolf lamp, sectional elevation

of usefulness at mines and quarries. The former are often employed below ground where the excavations take the form of huge underground chambers, such as may be seen in certain salt mines, slate mines and even lead mines. Above ground the arc lamp serves to illuminate open workings at night, as well as pit banks and sidings.

Fixed glow lamps form a convenient and desirable means of lighting up pit bottoms, on setting places, levels or sidings where the traffic is large, and ladder-ways or man-engines which are much frequented. Again, in sinking shafts, a cluster of incan-

descent lamps hung from an electric cable will enable the miner to do his work under unaccustomed conditions of brilliancy. While the blasting is going on, the lamps are drawn up out of the way of the stones which might be hurled up and break the glasses. But their use does not cease here; for at one of the mines on the Comstock lode,* candles have been entirely discarded even at the working faces and in the stopes, and have been replaced by incandescent lamps supplied with electricity by special cables.

During the last few years many forms of portable glow lamps have been tried at collieries, with the object of providing the miner with a safer and more brilliant light. The only lamp which has attained any measure of success is the Sussmann (fig. 247). Several thousands of them are now in daily use in England and Belgium. Two accumulator cells supply a current which passes through the usual fibre and causes it to glow. The bulb D is protected by an outer glass B and provided with reflector E and F. The lamp weighs 4 to $4\frac{1}{4}$ lbs. and will give a light of $1\frac{1}{2}$ candle power for 12 to 14 hours; the cost of the lamp, including all expenses, is from 4d. to 5d. per week. The only fault found with the lamp by its opponents is that it does not indicate the presence of fire-damp; this objection is not found to outweigh the other merits of the lamp by the colliery owners who employ it.

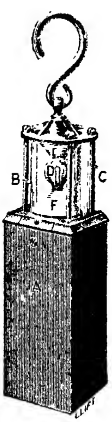


FIG. 247.—Sussmann electric lamp.

(7) Miscellaneous Lamps.

Among these must be mentioned ordinary gas lamps, acetylene lamps, the Wells lamp and its congeners, and finally the Kitson lamp.

The use of ordinary illuminating gas at the surface is too well understood to need any remark; it is occasionally employed for lighting pit bottoms, sidings or levels with much traffic.

Portable acetylene lamps are already carried by the agents of some mines, who are anxious to have a more brilliant flame than

* Hall, "Electrical Equipment of the C. & C. Shaft of the Consolidated California and Virginia City Mining Co., Virginia City, Nev.," *Mines and Minerals*, vol. xxiii., 1902, p. 159.

that afforded by oil or tallow. They have likewise found a successful application in the case of sinking shafts.

The Wells lamp, which is much used for surface works, also serves to illuminate large underground chambers for special purposes, such as examining the roof. It is a contrivance for burning tar oils converted into gas, when forced through a heated burner by pressure produced by a hand air-pump. The flame is from 1 ft. to $2\frac{1}{2}$ ft. in length, and gives a light of 500 to 4000 candles.

In the Kitson lamp * a mixture of petroleum vapour and air is burnt under an incandescent mantle, resembling the Welsbach mantle, with which most people using gas are now familiar. The petroleum is converted into vapour by the heat of the flame, and, save at the moment of lighting, the lamp is self-supporting. The contractors' lamp adopted for out-of-door work is readily carried by two men. Kitson reckons that an illuminating power of 1000 standard candles is obtained at a cost per hour of $\frac{1}{2}$d.

* Kitson, "Petroleum Incandescent Lighting," *Jour. Soc. Arts*, vol. li., 1903, p. 445.

CHAPTER XII.

ACCESS.

When we consider the time occupied by the miner in going to and from his work, and recollect that his hours are usually reckoned 'from bank to bank'—i.e. from the moment he leaves the surface to the time he reaches it again—and if we further reflect upon the terrible waste of energy in some mines from climbing down and up deep shafts, it will be evident that the question of 'access' cannot be dismissed without discussion.

The methods of access are: (1) Walking; (2) using steps or slides; (3) climbing ladders; (4) riding in bucket, skip or cage; (5) riding on man engine; (6) riding in waggons; (7) riding on velocipedes.

(1) Walking.

When mines are worked by adit levels, the men naturally walk in and out along these nearly horizontal roadways, and when mines are entered by shafts the men still may have to travel long distances on foot before reaching their working places. To save all unnecessary expenditure of muscular energy, the work of walking should be made as easy as possible; let the main walking ways be high enough for an ordinary man to stand up in without stooping, and let the pathway be smooth and dry. If the miner has to bend down to save his head from knocks and has to pick his way over rough stones and through a succession of puddles, time will be lost and energy wasted. Cases will naturally arise in which the expenditure to be incurred for making and maintaining high roadways would be out of all proportion to the benefits of being able to walk in an upright posture; the men will then be obliged to stoop, but they can relieve the muscles of their backs by using walking sticks.

(2) Steps and Slides.

If the dip of a seam is small, an inclined pathway, leading through the old workings if convenient, forms a safe means of access into the mine, and it has the further advantage that horses or ponies can be brought out easily at the end of each shift.

When the inclination reaches 20° it is well to have regular steps; these may be cut in the rock itself if it is hard enough; and if not, wooden or stone steps can be put in with a handrail. A very high dip makes a straight line of steps awkward; where there is sufficient space the difficulty is easily overcome by arranging the steps or stairs in a zigzag line. The tread or height of each step should not exceed 8 in., so as to avoid a fatiguing lift of the foot.

In some of the Austrian salt-mines the men descend from level to level, a vertical distance of 100 to 130 ft., by wooden slides inclined at angles varying from 30° to 50°, flattening at the bottom so as to reduce the velocity gradually; the miner can increase his speed by leaning forwards or lessen it by leaning back. The ascent is by steps. The Somersetshire collier* sometimes goes to his work in a similar fashion, when he can find an underground incline with a slope of 20° to 30°. Sitting upon a special piece of board with a groove shod with steel which fits the rail, he toboggans down distances of 100 to even 500 yards.

(3) Ladders.

Ladders are very largely used in ore-mines all over the world, but they vary a good deal in different countries.

The ordinary ladder consists of two sides and a series of rungs (*staves*, Cornwall). The principal points that have to be considered are the material, the size, and the mode of fixing.

In this country the mine ladder is most commonly made with wooden sides and iron rungs. On the Continent wooden rungs are common, and oak is preferred on account of its durability; the wooden stave is often made flat, instead of round, so that it may last longer, and iron sides may be seen where dry rot is very bad. In places where an ordinary ladder would be knocked to pieces by blasting, such as the bottom of a shaft in course of sinking, a short piece of chain ladder is put in; the sides are made of pieces of chain, and iron rungs are put in at suitable intervals.

* Information supplied by Mr S. C. Dunn, A.R.S.M.

The distance between the rungs is an important point. Experience shows that a distance of 10 in. from centre to centre is very suitable; ladders with steps further apart are far more fatiguing to climb.

Platforms (*sollars*, Cornwall) should be fixed at short intervals; though our British law allows them to be placed 60 ft. apart, the distance can be reduced with great advantage to 30 ft. or even less in perpendicular or highly inclined shafts. One side of the ladder may be fastened to timber in the shaft by strong staples; and if not, it should be kept rigid by stays so as to prevent any swaying.

The most convenient angle of inclination for ladders is about 20° from the vertical.

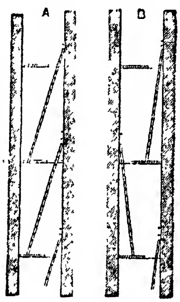


FIG. 248.—Ladders in shafts.

Of the two arrangements shown in fig. 248, A is better than B, because it not only affords a greater inclination for the ladders, but also renders it less likely that a man will drop through the opening (*manhole*) in the platform (*sollar*) if he loses his hold and falls. By law, in this country, the ladder compartment of a shaft has to be partitioned off from the winding compartment; a better plan is to provide an entirely separate shaft for a footway.

When a mine has reached a depth of 100 yards and upwards, mechanical appliances should certainly be introduced for raising or lowering the men, because time and strength are wasted by climbing; besides which, medical men are agreed that excessive ladder-climbing is injurious to the health of the miner. Therefore upon hygienic as well as upon financial grounds, one of the first thoughts in working a mine should be the conveyance of the men down and up the shaft with the least possible fatigue, by means of machinery.

(4) Buckets, Skips, and Cages.

This method of going down and coming up from mines recommends itself by its simplicity, and when carried out with modern appliances it is remarkably safe.

If the machinery is worked by hand, the miner usually stands with one foot in the kibble and uses the other to guide himself, while he holds the rope in his hands; this guiding is specially

necessary when going down an inclined winze with rough and rugged sides. Some men prefer to have one foot in a loop at the end of a rope, whilst others prefer a special stirrup.

Guides are compulsory in this country after a depth of 50 yards is exceeded, unless the owner of the mines has obtained an exemption from the inspector of the district. In the chapter on winding I have explained how guides can be applied to the kibble or bucket even in a sinking shaft; but the usual method of ascent and descent is by the cage, or some form of guided box. The process of lowering and raising is practically the same as that of winding mineral. Rules are made defining the number of men allowed to ride at one time, and generally there is a bar near the top of the cage which the men can hold, in case there should be any little jerks.

The British law demands that, in addition to the guides already mentioned, there should be a cover overhead, so as to protect the men from things falling down the shaft. The use of a single linked chain is forbidden, except for the short coupling piece connecting the cage to the rope. There must be flanges to prevent the rope slipping off the drum; the winding machine has to be provided with an adequate break and a proper indicator; and, lastly, there must be a means of signalling up and down from every landing place in the shaft. In some countries safety-catches are compulsory.

At mines under the Coal Mines Act in this country, the rate of winding must not exceed three miles an hour after the cage has reached a point in the shaft which is fixed by Special Rules. However, this regulation applies only in cases where the hoisting apparatus is not provided with some automatic contrivance to prevent overwinding. In Germany a speed indicator has to be applied when men are being raised or lowered; among instruments of this class may be mentioned the tachometer of Messrs Schäffer & Budenberg, with a pointer which indicates the rate of winding on a dial in full view of the engineman. Karlik's speed-measurer not only notifies the velocity by a pointer, but also records it automatically on paper; the winding engine shown in fig. 187 is provided with this apparatus.

Winding by the cage is not necessarily confined to perpendicular shafts.

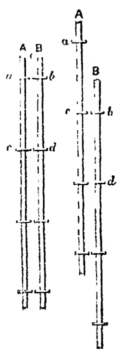
(5) Man-engine.

Two kinds of man-engines are in use, the double-rod and the single-rod machine.

The double rod or original man-engine consists of two recipro-

cating rods, like the main rods of pumps, carrying small platforms or steps, upon which the men stand. The stroke is from 4 to 16 ft., and the little platforms are arranged so that they are always opposite each other at the beginning and end of each stroke.

Figs. 249 and 250 represent the rods in the two final positions. A man who wishes to go down, steps upon platform *b* (fig. 249); the rod B goes down and A goes up, so that *b* is brought opposite *c* (fig. 250). The man steps across from *b* to *c*, the rod A makes a down-stroke and B an up-stroke. Platform *c* is now opposite *d* (fig. 249), and the man again steps across; and thus, by constantly stepping from the rod as it completes its down stroke, the man is gradually conveyed to the bottom of the shaft. By reversing the process, or, in other words, by stepping on to the opposite platform as soon as the rod has completed its up-stroke, the man is raised to the surface without any fatigue beyond the very slight effort of stepping sideways. If each rod makes four up and down strokes of 10 ft. each per minute, the rate of ascent or descent will be 80 ft per minute.



FIGS. 249 and 250 — Double - rod man-engine.

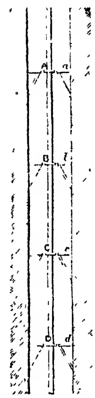


FIG. 251.—Single-rod man-engine.

The single rod man-engine has one rod carrying steps, while fixed platforms are arranged in the shaft so as to correspond exactly with them (fig. 251). If a man wants to go down he steps on to A when the up-stroke is completed; the rod goes down and the step A is brought opposite the fixed platform *b*, on to which he steps off. He then waits on *b* until the rod has finished its up-stroke. B is brought opposite *b*; he steps on to B, the rod goes down and he is brought opposite *c*, where he again steps off and waits. By reversing the operation he is gradually lifted up to the top of the shaft. The single rod engine may be used by men going up while others are going down, provided that there is sufficient room upon the fixed platforms. It is best

to have platforms . . . and left, as shown in the figure, and then the ascending men step off always to the left, for instance, while the descending men take the right hand sollars.

The man-engine has the advantage that it can be safely applied in inclined and crooked shafts, and it is convenient in vein mining where the men have to work at very many different levels.

Judging by what has taken place during the few years, it seems likely that the man-engine will eventually die a natural death, and be replaced by the safer and more convenient cage.

(6) Waggons.

As a rule the miner walks from the pit bottom to his working place; when this distance is great, the mine is generally equipped with some form of mechanical haulage and the men may be sent 'in-bye' and brought 'out bye' in mine waggons, with the object of economising their time and husbanding their strength.

The line of demarcation between 'haulage' and 'winding' is vague and undefined. What some people call a 'shaft' will be designated an 'incline' by others; if the dip is not very steep, the men may be lowered and raised in vehicles resembling the cars on mountain railways, with benches arranged in tiers one above the other.

(7) Velocipedes.

These machines are of service in long adit levels, and especially for superintendents.

CHAPTER XIII.

DRESSING.

In a large number of cases the mineral is not ready for sale when raised from the mine, and consequently it has to be subjected to some kind of special treatment in order to be fitted for the market.

The processes of treatment may be classified as follows:—

A. Mechanical Processes.

(1) *Washing.*
(2) *Hand-picking*
(3) *Breaking up, subdivision*, or *shaping.*
(4) *Agglomeration* or *consolidation.*
(5) *Screening* or *sifting.*

B. Processes depending upon physical properties.

(6) *Motion in water.*
(7) *Motion in air.*
(8) *Desiccation.*
(9) *Fusion.*
(10) *Magnetic attraction.*
(11) *Surface adhesion.*
(12) *Separation according to degree of friability.*

C. Processes depending upon chemical properties.

(13) *Solution, evaporation*, and *crystallisation.*
(14) *Atmospheric weathering.*
(15) *Calcination.*
(16) *Cementation*, or *precipitation by iron.*
(17) *Amalgamation.*
(18) *Distillation.*

A. Mechanical Processes.

(1) Washing.

Sometimes the mineral coming from the mine requires to be freed from adhering particles of clay, in order to be rendered fit for sale; at other times, the clayey particles are the valuable material and have to be separated from worthless stones; and thirdly, cleansing is desirable in order to facilitate sorting by hand or other dressing processes.

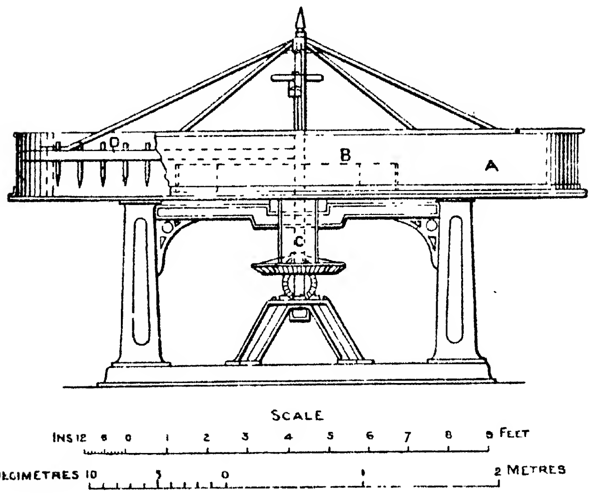


Fig. 252.—Rotary washer for diamond-bearing earth.

A rotary washing-machine (fig. 252) is employed at the South African diamond mines, to free the weathered 'blue ground' from the finest sand and mud, and leave clean gravel from which the diamonds are separated by subsequent processes. The rotary washer is an annular iron pan A, 8 to 15 ft. in diameter and 16 in. to 2 ft. deep externally, whilst the inner rim B, 4 ft. in diameter, is only 6 in. deep. In the centre is a vertical revolving shaft C, carrying eight or ten radial arms D, each provided with six or seven vertical blades which dip into the mud and gravel, and stir it up as they revolve. At De Beers mine the washers are usually

14 ft. in diameter. The stuff is fed in at the outer circumference by a shoot coming from a screen, and the muddy water escapes over the low inner rim of the pan. The teeth or stirring knives are arranged so as to bring the heavy gravel towards the circumference. As a precaution, the muddy water flowing out of the washer is run into a similar machine, and is stirred up so as to catch any diamonds which may by chance have escaped in the first operation. When the pan has been at work for twelve hours, a sliding door is pulled out at the bottom, through which the gravel falls into a truck underneath, as it is drawn round by scrapers attached to the arms.

(2) Hand-picking.

Various cases arise in practice: the useful mineral may be the main ingredient, and the refuse form only a small proportion of the stuff brought up from underground, or *vice versâ*. The former state of things happens with coal, which is frequently more or less mixed with shale. The product of the mine is carried by a broad travelling belt past boys and girls or women, who pick out and put aside the refuse and let the clean coal pass along. With diamonds we have the reverse. The washed gravel contains an extremely small proportion of the gems, and in this case it is the valuable mineral which has to be picked out by the workman, whilst the waste is left behind.

Between these two extremes are all sorts of intermediate cases; the product of the mine may contain the ores of two or three metals, and the lumps may vary greatly in richness, so that instead of merely separating good and bad, as is done in the instances cited above, the picker may have to make several categories, of various qualities and various degrees of purity. Figs. 173 and 174 show Robins belt conveyors used as picking tables.

(3) Breaking up, Subdivision, or Shaping.

The chief object of breaking up the stuff coming from the mine is to set free the particles of the valuable mineral which are enclosed in, or adhering to, particles of refuse. The breaking may be done by hand or by machinery.

The hand processes are as follows:—

Big blocks are broken up by sledge hammers; pieces of mixed ore and veinstone have the refuse knocked off by 'cobbing' hammers; lumps of ore are reduced to a coarse powder by flat 'bucking' hammers; slate is split by wedges into thin sheets and trimmed into rectangular pieces by a long knife, and blocks of

freestone are [illegible] with the axe or saw; paving stones are shaped by special hammers.

The most important kinds of machines for breaking up minerals are :—

(*a*) Rock breakers with reciprocating jaws
(*b*) Rock-breakers with 'gyratory' action.
(*c*) Stamps.
(*d*) Rolls.
(*e*) Disintegrators.

(*a*) The ordinary stone breaker or rock breaker is a machine with two jaws, one of which is made to approach the other, and so crack any stone which lies between them. The best known stone-breaker is the machine invented by Blake. Its mode of

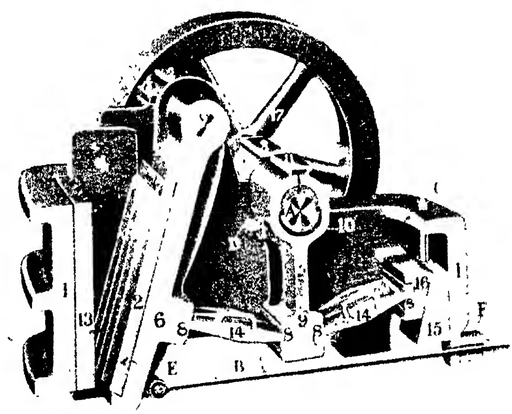


FIG. 253 —Blake's rock-breaker, as improved by Hadfield & Jack.*

1. Main frame, made of cast steel.
2. Cap of bearing of movable jaw.
3. Cap of bearing of excentric shaft
4. Cheek
6. Movable jaw.
7 Wedge for movable jaw
8, 8, 8, 8. Toggle cushions.

9 Pit man.
10 Brass bush
11. Cover of oil box.
12 Replaceable plate of movable jaw
13 Replaceable plate of fixed jaw.
14, 14 Toggles
15. Adjusting wedge.
16. Adjusting toggle block.

17 Fly wheel.

A. Excentric shaft.
B. Drawback rod.
C. Adjusting nut.
D Cotter.
E Bolt of drawback rod.
F. Spring of drawback rod.
G Cotter bolts.

* Figure reproduced by permission of Hadfield's Steel Foundry Co., Ltd.

action is very simple. When the shaft A (fig. 253) revolves, an excentric raises the pitman 9, and by means of the toggle-plates 14, 14, causes the movable jaw 6 to approach the fixed jaw 13, and so crack any stones lying between them. During the descent of the pitman the jaw 6 is drawn back by an india-rubber spring F. The jaws are usually toothed, the ridges of one jaw being opposite the grooves of the other when the machine is employed for breaking stones at mines. If the object is to make road metal, the two sets of ridges are brought opposite each other. The wearing parts, 12 and 13, of the two jaws are replaceable, and if these castings cannot be immediately obtained in a distant country, it is possible to do good work with flat plates of steel.

(*b*) As an example of a machine with 'gyratory' action, I will take the Heclon breaker of Hadfield's Steel Foundry Co., Ltd. (fig. 254).* It consists of an outer conical cup lined with manganese steel O O, and an inner conical centre R, fitted with a mantle S of the same metal The inner cone hangs from the ball P, which is carried by the central shaft 1.

This shaft is provided with an excentric G^1, which revolves inside the hollow shaft T, when the driving pulley J sets in motion the pinion H and the bevel wheel G. The revolution of the excentric causes the hollow shaft T, and with it the conical centre R S, to be constantly approaching or receding from the outer cone. Stones lying between the two cones are consequently cracked, and the pieces which are fine enough fall down on to the sloping bottom shell A Z^3 A. The motion of the shaft T, and inner cone, will be easily understood by holding up the end of a pencil, point downwards, between the forefinger and thumb of the left hand, and then making the point describe a circle upon a piece of paper lying horizontally, without any revolution of the axis of the pencil. This is what is meant by the makers of these conical breakers when they speak of the motion of the cone as 'gyratory,' or say that the cone 'gyrates.'

(*c*) The simplest mode of describing stamps is to say that they are pestles lifted by machinery and dropping into large mortars. In most cases the blow of the pestle is caused by gravity alone.

A little study of the accompanying figures will explain the most important characteristics of a modern stamp battery.

A A (fig. 255) are blocks of timber forming the solid foundation, which is required on account of the heavy pounding action of the machinery; B B the transverse sills, with the battery posts C C, the braces E and the tie-timbers D D form the framework

* Reproduced by permission of the Company.

holding the mortar or battery box F, in which the mineral is pounded by any one of the five stamps moving up and down in it.

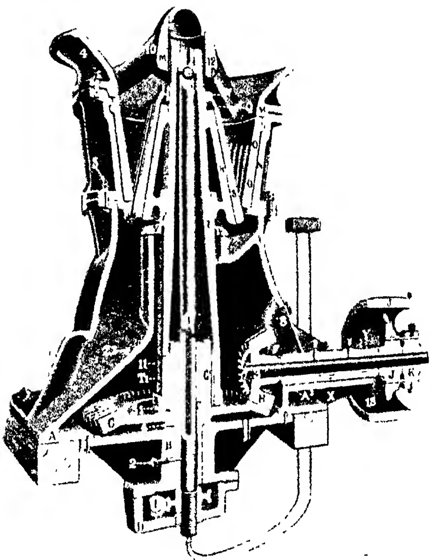


FIG. 254 -Hadfield & Jack's patent gyratory rock and ore breaker.

A. Bottom shell.
B. Bottom plate
C. Sleeve.
D. Worm wheel box.
E. Worm wheel.
F. Worm.
G. Bevel wheel
G^1. Excentric.
H. Bevel pinion.
J. Belt pulley.
K. Break pin hub.
L. Dust cap.
M. Hopper and spider.
N. Top shell.
O. Concaves of Hadfield's patent manganese steel
P. Ball bearing
Q. Holding down washer.
R. Cast steel centre.
S. Mantle of Hadfield's patent manganese steel
T. Hollow shaft.
V. Dust ring.
W. Ring nut.
X. Bearing for countershaft
Y. [illegible]
A^3. Countershaft wearing ring
S^1. Dust collar.
T^1. Cast steel centre for white metal lining
Z^3. Hadfield's patent manganese steel wearing plates.
1. Central shaft.
2. Tightening screw.
3. Counter shaft.
4. Spider bolts.
5. Mid-joint bolts.
6. Main shaft wearing ring.
7. Nuts for bearings.
8. Wrought iron dust door.
10. Cast steel top bush.
11. White metal bush
12. Ball socket.
13. Break pin.

G is a perforated screen or plate which prevents the mineral from leaving the mortar until it has been brought down to the required

degree of fineness. H is the shaft carrying cams, which lift the stems by tappets; K K are the ends of the stems of the stamps proper; L is the pulley through which motion is transmitted to the cam shaft by the belt of the driving pulley M. N is the gear by means of which the driving belt can be tightened. Each stamp proper, K K, consists of a turned rod of iron with tapering ends, either of which will fit into a corresponding hole in a cast iron cylinder known as the 'head' (figs. 256 and 258).

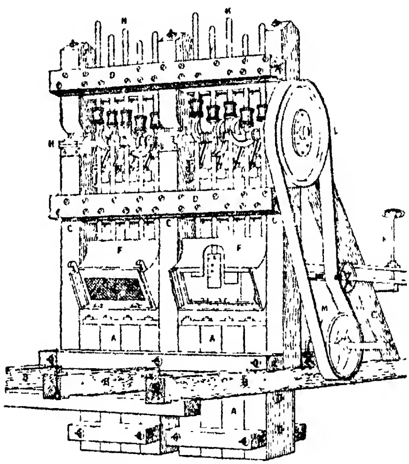
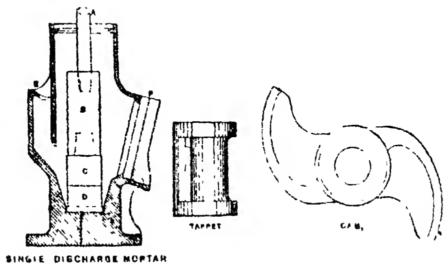


FIG. 255.—Stamp battery.

The conical hole or socket in the bottom of the head receives the shank of the 'shoe,' which is made of cast iron, cast steel, or forged steel. When worn, the shoe can be removed from the head by driving a steel key into a slot above it (fig. 258), and the stem or lifter is extracted in a similar manner by means of a second slot at right angles to the first.

The mortar is shown on a large scale in fig. 256. It is a cast-iron box with an opening E at the back for feeding, and one in front, fitted with a screen, for the discharge. Fig. 257 represents the tappet, a hollow cylinder of cast iron, which is fastened to the lifter by steel keys and a gib. The gib is a piece of wrought

iron fitting the [illegible] surface of the lifter and capable of being tightly jammed against it when steel keys are driven into three holes in the tappet. As the shaft H revolves, the cams (figs. 255



FIGS 256, 257 and 258. -Mortar, tappet, and cam

and 258) lift the tappets, and at the same time cause a slight rotation of the stamp which conduces to regular and even wear

The head B, with its shoe C (fig. 256), drops down upon a cylinder of similar metal known as the die, and it is between C and D that the mineral is pulverised Both shoe and die wear away and have to be changed from time to time.

The screens through which the pulverised mineral has to pass are made of plates of punched iron, steel, or copper, and occasionally of wire gauze. The punched holes are round or in the form of long narrow slots.

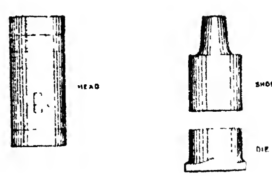


FIG. 259.—Head and shoe of stamp, and die.

The total weight of each stamp when new, that is to say stem, head, and shoe, varies from 450 to 1750 lbs.; weights of 800 to 1050 lbs. are common. The height of the drop varies generally from 6 to 12 in., and there are 70 to 105 drops per minute. Ore may be stamped dry or wet; in the latter case, water constantly flowing into the mortar box carries off the mineral through the screens in the form of a muddy stream know as 'pulp.' It is estimated that the quantity of water used in wet stamping is from $\frac{1}{4}$ to $\frac{1}{3}$ cub. ft. per stamp per minute, or 200 to 300 cub. ft. per ton of rock stamped.

The quantity stamped per head per day must necessarily vary within very wide limits, according to the weight of the stamps, the nature of the stone treated, and the degree of fineness desired. On the Rand with coarse crushing for tube mills each head will stamp 9 or 10 tons in twenty-four hours.

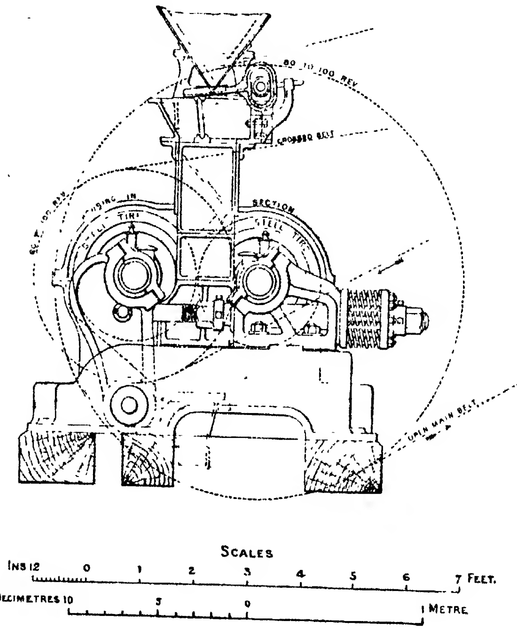


FIG. 260.—Krom's crushing rolls.

(d) Rolls were introduced into the west of England in the early part of the last century to replace 'bucking' by hand. They are a pair of smooth, fluted, or toothed cylinders, made of cast iron or steel, which revolve in opposite directions, and crush any stone which is allowed to fall between them.

The cylinders are usually from 1 ft. to 3 ft. in diameter, and 1 ft. to 3 ft. wide; they are generally kept pressed together by levers or springs.

(e) The best known disintegrator is Carr's (fig. 261). It may be described as consisting of two cylindrical cages revolving in opposite directions. Each cage is made up of two concentric sets of bars attached to a disc on one side and to a ring on the other. The stuff which is fed into the centre is thrown by the bars *a a* of the cage X, against the bars *b b* of the cage Y, thence it flies against the outer circle of bars *c c* of X, and finally against the outer circle of bars *d* of the cage Y. It then enters the circumferential space *e*, whence it can be allowed to escape by a suitable opening in the outer casing *f*.

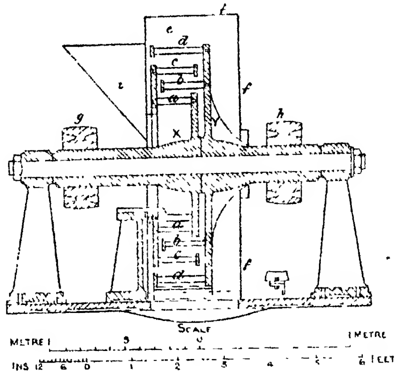


FIG. 261.—Carr's disintegrator

In conclusion it will be well to point out the uses to which the various kinds of crushing machines are applied, viz. :

α. Preliminary breaking . .	Jaw breakers, and 'gyratory' breakers.
β. Coarse crushing	Rolls.
γ. Fine crushing	Stamps, rolls, mills of various descriptions, and disintegrators.

(4) Agglomeration or Consolidation.

Processes of this kind are more particularly used in the case of coal or brown coal, small particles of which can be pressed by machinery, either with or without the addition of some cementing material, into blocks of fuel of convenient shapes and sizes. The product is known to us as 'patent fuel,' though the French term

'briquette' is likewise applied. Agglomeration is not confined to coal; fine iron ore, such as is furnished by the magnetic separators, would choke the blast furnaces if used alone in the powdered form, and has to be made up into solid lumps. Edison adds a little pitch to the powdery ore and presses it into short cylindrical 'briquettes' about 3 in. in diameter and 1 to 1½ in. thick. When magnetic concentration comes more largely into use, briquetting machinery will play as important a part in the dressing plant of some iron mines as it does already at certain collieries.

(5) Screening.

Screening may be necessary for various reasons, such as securing comminution to a given degree of fineness, separating small particles disliked by the consumer, and dividing the mineral into classes containing fragments of approximately uniform size. Thus the screen of the stamps (fig. 255) prevents the exit of any particles of ore until they have been crushed sufficiently; fine coal is separated from the more marketable lumps; uniformity in size is desirable in the case of anthracite for facilitating combustion, and is a necessary preliminary to 'jigging' in the case of many metallic ores.

Screens may be flat, cylindrical or conical in shape; the two latter kinds are known as trommels. Screens are made of woven wire cloth or punched sheet metal, or are formed by a series of paralled bars. The flat screen usually receives some form of reciprocating or vibrating motion, or the bars of the grating may be made to move up and down; the trommels are made to revolve.

The flat screen does far more work per square foot of surface than the trommel, because the material is spread all over it instead of lying along a line at the bottom.

Fig. 262 shows a common kind of trommel in the form of a truncated cone. A is the feed end, B the cast-iron supporting ring; C, E and F are sieves, D a sheet-iron plate. What fails to pass through C runs over to D and is discharged at H; what passes through C falls on to E. Some goes through and the remainder runs on to F. Here again some drops through, and the coarser particles leave at G. Four sizes are separated by this trommel.

Among recent improvements in screens may be mentioned those of Mr W. W. Beaumont and Mr W. McDermott. The 'vibromotor' of the former inventor enables a flat sieve to be worked with less wear and tear and with a smaller amount of power than the ordinary oscillating and shaking screens.

Mr McDermott's screen is worked under water; it is not unlike a jig save that the sieve is sloping. The stuff is fed on to the upper end of the screen, which is lying in a bath of water, and it is subjected to pulsations in the water, produced in the same manner as the pulsations of a jig by a piston moving up and down in an adjoining tank. The screen is kept from clogging, and it does not wear so much as that of a trommel. The work of sizing is said to be carried out very effectually by this new appliance.

B. Processes depending upon Physical Properties.

(6) Motion in Water.

Where the valuable mineral and the waste with which it is mixed differ sufficiently in specific gravity, they may be separated by a mere fall through water.

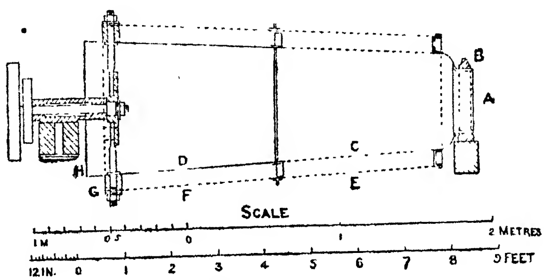


FIG. 262.—Revolving screen or trommel.

A piece of galena with a specific gravity of 7·5 sinks to the bottom more quickly than a similar piece of quartz, the density of which is only 2·6. Nevertheless, a large piece of quartz may fall to the bottom as quickly as a small piece of galena. Particles which have equal velocities of fall though differing in size and specific gravity, are said to be *equal-falling*, or *equivalent*. P. von Rittinger shows that a sphere of quartz of 4 mm. in diameter would sink in water exactly as quickly as a sphere of galena of 1 mm. in diameter, and these two particles are therefore equal-falling. Consequently, before we can separate properly by water, it is desirable to classify the particles by size, so that equivalence

shall not prevent a separation or lessen its sharpness. It is nevertheless true that in the early part of the fall of equivalent grains the influence of the specific gravity preponderates, and the denser particles take the lead; therefore, by a frequent repetition of very small falls, particles which have not been closely sized may still be separated.

The principal machine for concentrating particles varying in size from 1 in. to $\frac{1}{60}$ in. is the jigger. The hand jigger is merely a round sieve which is charged with the crushed mineral and then moved up and down in a tub full of water. Each time that the sieve is lowered sharply into the water, the particles are free to drop a short distance, and they gradually arrange themselves in layers, the heaviest at the bottom and the lightest at the top. On lifting out the sieve the layer of specifically lighter minerals can be skimmed off with a scraper, leaving a layer of the specifically heavier minerals at the bottom to be removed separately.

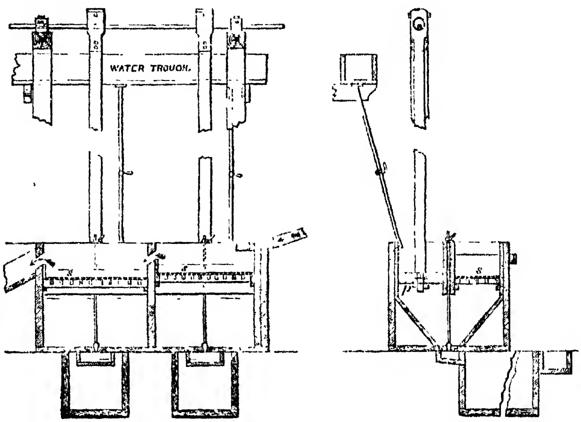
According to circumstances the valuable material to be extracted may be the heavier or the lighter.

The desire to treat large quantities with speed and economy has led to the introduction of machines working continuously, and the continuous jigger is one of the most useful dressing machines of the present day, both from the point of view of the ore miner and of the collier. It consists of a box or vat divided by a partial partition into two compartments; in one is fixed a flat sieve *s* (figs. 263 and 264), which carries the mineral, in the other a piston *p* is made to work up and down by an excentric. The vat being full of water, the movement of the piston causes the water to rise up and fall down through the mixed minerals, lifting them and letting them fall repeatedly. The effect of these frequent lifts and falls is to cause a separation into layers of heavy stuff at the bottom, light stuff at the top, and mixed stuff in the middle. If lead ore in a calcareous veinstone is being treated, we get clean galena at the bottom, clean calc spar at the top, with an intermediate layer of mixed galena and calc spar. The conditions are reversed in the case of coal mixed with shale, for here the useful mineral is lighter than the waste. When treated in the jigger the coal goes to the top and the shale sinks to the bottom.

The great advantage of the machine jiggers is that they readily allow a continuous feed of the stuff and a continuous discharge of the products without any stoppages. The stuff is fed on from a hopper placed at one end of the machine, or is delivered already mixed with water. The two commonest methods of discharge are at the end or through the meshes of the sieve.

With the first the heavy product lying on the sieve passes out through openings at the end of the jigger, and the amount escaping is regulated by an adjustable shutter which enables the size of the outlets to be increased or diminished at pleasure; the middle product can be drawn off by openings placed at a slightly higher level, whilst the light product is washed over a sill at the end of the sieve at each pulsation. Very often a first sieve simply separates a concentrated product and discharges a poorer product on to a second sieve where a similar separation is effected.

The discharge through the sieve is specially adapted for the



FIGS. 263 and 264.—Continuous jigging machine.

finer products from the crusher, though it is also used for grains up to and even above $\frac{1}{4}$ in. in diameter. The mesh of the sieve is chosen so that the particles under treatment will just pass through, but above the sieve is a layer of some substance of about the same density in fragments too large to drop through. The pulsations of the water cause the usual separation into layers, and the heavy particles find their way down through the bed of mineral of like specific gravity and drop into the vat below, whence they can be drawn off through a hole as required. The lighter particles pass over a simple sill at the end of the sieve, or to a second sieve if necessary. Three or four sieves are occasionally arranged in a row, if necessary, in one machine.

Another method of separating with the aid of water is to allow the fine particles to be carried down an inclined plane by a stream of water with the inclination of the plane and the quantity of water so regulated that the heavier particles will settle and the lighter ones be washed away.

A simple but largely used machine of this class is the Frue Vanner, which commends itself by its continuous action.

It is an endless band of india-rubber cloth, 4 ft. wide and 27 ft. long (fig. 265), supported by a frame with a number of small rollers on which it travels easily, when driven slowly in the direction of the arrows by the upper end roller shown in the figure. The small roller by the side of the large one, which dips into the tank, serves for tightening up the belt when required. The whole frame carrying the belt receives a motion sideways from three little cranks upon a small shaft running parallel to its length.

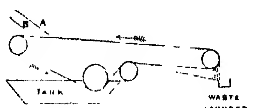


FIG. 265.—Frue vanner.

The stream of water and fine ore (*pulp*) is fed on at A, clean water at B. The natural path of the orey stream is down the inclined belt, but the specifically heavier particles settle upon it and are carried upwards. Those that can resist the action of the stream of clean water at B go over the end and are washed off as the belt passes through the tank. The poor stuff falls into a waste launder. The degree of concentration can be regulated by the slope and speed of the belt and the strength of the streams of ore and water.

The Elliott coal washer* (fig. 266) is a wrought iron or steel

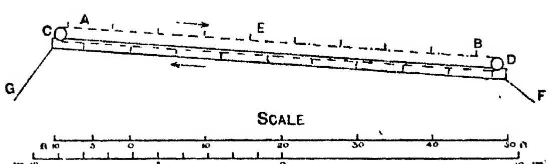


FIG. 266.—Elliott coal washer.

trough about 60 ft. long and 18 in. wide at the bottom, with sides sloping outwards. An endless chain A B turning upon sprocket wheels C D drags a number of hoe like scrapers along the

* From a drawing supplied by the Hardy Patent Pick Co., of Sheffield.

trough, whilst the coal is fed in at E and water near A. The size of the stream of water and the slope of the trough are so arranged that the light coal is washed down and discharged at F, whilst the heavier shale and pyrites are dragged up against the current and shot over the upper end of the trough at G. The apparatus is exceedingly simple, and a 60-ft. trough will wash from 100 to 125 tons of coal a day.

(7) Motion in Air.

In countries where water is scarce, or when the valuable mineral is specially liable to be affected or carried off by water, air may be employed as a medium in which concentration takes place; however, pneumatic machines are not largely employed for dressing purposes.

(8) Desiccation.

Minerals have to be dried in order to get rid of moisture objectionable to the buyer, or interfering with subsequent operations, such as briquetting, pneumatic concentration, or certain forms of magnetic separation. Drying may be carried on in one of the following ways:—Exposure to the air, open fires, heated floors or pans, stoves or kilns, filter presses.

(9) Fusion.

A difference between the melting-point of the valuable mineral and that of the accompanying waste serves in a few cases as a basis of separation. Sulphur begins to melt at a temperature of 114°·5 C. and becomes thoroughly liquid at 120°; consequently when sulphur-bearing limestone is heated, the sulphur runs out in a fairly pure state, leaving the waste behind. Practically the whole of the sulphur of Sicily is obtained by processes dependent upon this simple fact.

(10) Magnetism.

This force was at first used simply for extracting, by means of a permanent or an electro magnet, a rich concentrate of magnetite from ores comparatively poor in that mineral; it was next employed for the purpose of removing magnetite from ores in which it played the part of troublesome refuse. Later, mixtures of chalybite and blende were roasted in order to convert the former into magnetic oxide and so render it easily separable.

The blende when freed from iron became rich enough for sale.

One of the machines which has been largely employed in Sweden for the purpose of concentrating poor magnetic iron ore is that of Wenstrom (fig. 266).

Wenstrom's magnetic separator has a stationary electro-magnet A and a revolving armature barrel B, consisting of a number of soft iron bars separated by strips of wood. The electro magnet lies on one side of the centre of the barrel, so that the iron bars of the armature become magnetised during only a part of the revolution. C is a tray feeding ore on to the top of the barrel, D a shoot for the non-magnetic particles, and E a shoot for the concentrate. The magnetic grains adhere to the soft iron bars when these are near the electro-magnet, and are carried past D as the barrel revolves; but as the bars recede from the electro magnet they lose their power of attraction and let the iron ore drop into E.

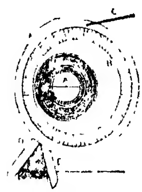


FIG. 266.—Wenström's magnetic separator.

Wetherill* was the first to point out that magnetism could be successfully used on a commercial scale for extracting minerals hitherto considered as non-magnetic or only feebly magnetic. Among these minerals may be mentioned specular iron, red hæmatite, brown hæmatite, lazurite, buntkupfererz, copper pyrites, fahlerz, zinc blende, monazite, wolfram, apatite, and ferruginous minerals such as mica, hornblende, serpentine, asbestos, etc. The principle of all the Wetherill machines is the production of a magnetic field with such powerful lines of force that even feebly magnetic substances are attracted.

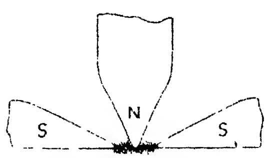


FIG. 267.—Magnet of one of the Wetherill separators.

Various arrangements have been and are in use for the purpose. A machine employed with success in Germany for separating spathose iron from zinc blende has its magnets arranged as shown in fig. 267. A main pole N in the middle has two poles S and S at the sides with the object of giving a long magnetic field.

Fig. 268 explains how the work is carried out. A large electro-

* Schnelle, "Die neuesten Fortschritte auf dem Gebiete der magnetischen Aufbereitung," *Verhandlungen des Vereins zur Beforderung des Gewerbfleisses*, 6th Oct., 1902.

magnet has its wedge-shaped pole enclosed between the two poles of a piece of wrought iron, corresponding to S and S of fig. 267. When a current passes through the coil, a powerful magnetic field is generated where the three edges come together.

The ore contained in a hopper is fed by a revolving roller on to a belt B which passes around the two rollers, and is driven in the direction of the arrow. The roller R is so arranged that the belt discharges its contents within the magnetic field. Non-magnetic particles drop at once, whilst the magnetic particles are carried towards the poles and would stick to them were it not for the belt B, revolving round the two rollers N and M. The magnetic particles travel a little way with the belt and finally drop. By arranging suitable partitions it is easy to make three products, viz., clean spath se... falling in the left hand compartment, blende in the right hand one, and a middle product between them.

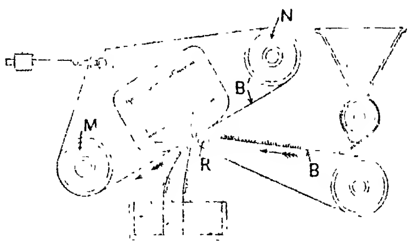


FIG. 268.—Wetherill magnetic separator.

Several other forms of Wetherill separators are made, and one of them can be employed for ores in the wet state.

In a similar manner blende or copper ore may be separated from iron pyrites, blende from copper ore, garnets and titanic iron from diamonds, wolfram from tin ore, and monazite from quartz.

(11) Surface Adhesion.

It is only within the last few years that this property has been made use of in dressing. Diamonds stick to grease more readily than other minerals; consequently if the concentrate from the jiggers containing diamonds, garnets, zircons, disthene, diopside, enstatite, magnetite, titaniferous iron, pyrites, olivine, etc., is washed down an inclined plane covered with a thin layer of grease, the diamonds adhere and the other minerals are washed off. This process saves a large amount of handpicking.

I believe Mr. Robson was the first to point out that petroleum sticks to many of the metallic ores and not to earthy minerals, and that a system of concentration may be based upon this property. The process was improved by Elmore, who, using an excess of oil, floated the concentrates to the surface of water and subsequently separated them from the oil by treating the mixture in a centrifugal drier. This has been superseded by the Elmore Vacuum process, a small quantity of oil being used and the air bubbles released from water, under a partial vacuum attaching themselves to the oiled sulphides and floating them to the surface. The separation is effected in a chamber at the top of a siphon, down the long leg of which the tailings are continuously delivered.

(12) Friability.

Some minerals are more easily crumbled and reduced to powder than others; and if the difference in friability is great, it is possible after crushing to effect a separation by a mere process of sifting. An instance of this rare method of concentration occurs at the graphite mines near Passau, in Bavaria. The softer kinds of mineral obtained from the mine are ground in mills, when the thin greasy elastic plates of graphite arrange themselves parallelly to the surface of the stones, and preserve their flat shape, while pieces of more brittle minerals are reduced to the state of fine powder. The ground product is sifted upon fine silk cloth; the dust, poor in graphite, passes through the fine holes, but the scales of graphite are left behind.

C. Processes depending upon chemical properties.

(13) Solution, Evaporation and Crystallisation.

Processes of this kind are employed by the miner with minerals such as borax, nitrate of soda, potassium salts, and common salt, which are soluble in water.

Nitrate of soda is freed from the earthy matter with which it is contaminated by throwing the *caliche* into water, drawing off the solution and evaporating it until it crystallises.

The extraction of gold by a solution of cyanide of potassium must be regarded rather as a metallurgical than a mining process.

(14) Atmospheric Weathering.

When exposed to the atmosphere certain minerals and rocks gradually disintegrate, and the crumbling up may set free valu-

able constituents which were previously tightly shut up in an earthy shell, and so facilitate their separation by subsequent processes. It is especially in the case of diamond-bearing rock that a weathering action is carried out on a large scale and in a very systematic manner. The rock as it comes from the mines is spread over the ground and there left for months exposed to the atmosphere; the floors laid out at Kimberley for treating the 'blue ground' of the De Beers mine occupy some thousands of acres. After being left some time, the 'blue' is broken up by means of picks into pieces not larger than 4 inches cube, and is again left to dry for a further period, until most of the natural water has evaporated. The artificial 'diamond field' is then watered, to aid the disintegration, and lastly harrowed and rolled; in fact, the miner endeavours to bring about the pulverisation somewhat in the same way that the farmer prepares his land for tillage.

(15) Calcination.

The object of calcination or roasting may be:

a. To effect a change in the chemical composition of a valuable mineral, and so produce either an ordinary article of commerce or one that is more readily saleable than the raw material.

b. To effect a change in the chemical composition of some of the substances accompanying a valuable mineral, and so get rid of them or render them more easily separable by other processes.

The commonest example which can be cited is burning limestone; the action of heat is made use of to drive off the carbonic acid and leave quicklime. Another instance is furnished by clay ironstone, or any ore in which the iron occurs mainly in the form of carbonate. Simple exposure to heat converts ferrous carbonate into magnetic oxide; the former contains 48 per cent. of iron, the latter 72 per cent.; consequently, if the ore has to be sent to a distance there is a saving in freight, besides which the ore is more acceptable to the ironmaster for his furnaces.

Gypsum is calcined in order to expel the water chemically combined with it, and convert it into plaster of Paris.

Partially concentrated tin ore (*whits*) is roasted in order to convert iron pyrites and mispickel into pulverulent oxides which can easily be separated by washing.

(16) Cementation.

The famous old Parys mine in Anglesey affords the most important example of cementation carried on at a mine in this

country. Coppery water is pumped out of the mine, and is led into brick lined pits containing scrap iron. The iron is raked over from time to time, and eventually the old pots, kettles, shovels, meat tins, etc., pass into solution, while the copper is precipitated. The iron used is not lost; the ferruginous solution running away from the precipitating pits is led into large pools, and there exposed to the action of the air and rain. The dissolved iron gradually passes to a higher state of oxidation, producing insoluble ochres, and little by little a deposit of this substance forms upon the bottoms of the big ponds. According to the strength of the irony solution supplied, the ponds are run dry and cleared out once in every two or three months. Wind and rain aid the process of oxidation.

(17) Amalgamation.

Gold and silver are often extracted from their ores by amalgamation, that is to say, by processes based upon their affinity for mercury. In the case of silver ores the processes are often complex, and require the sulphide and other compounds of the precious metal to be brought into the state of chloride before amalgamation is possible; consequently the treatment of such ores belongs rather to the smelter than to the miner. On the other hand, with native gold the process is generally simple, and the ore goes straight from the pit to extraction works.

The amalgamation of gold takes place by mere contact, either when the particles touch the mercury as they slide or roll along in a current of water, or when they are in some way mechanically rubbed against it.

The gold-bearing gravel washed down by the hydraulic process (fig. 102) is conducted into long troughs with a movable pavement of wood, stone or iron, so arranged as to create eddies. These may suffice of themselves to collect the gold, but the extraction is often aided by adding mercury, for the particles of gold scoured by the rush of sandy water amalgamate with the quicksilver the moment they touch it.

Where gold quartz is stamped the process is somewhat different. The pulp discharged through the grates of the mortar box is allowed to flow over an inclined table, covered with a sheet of copper which has been amalgamated. The bright silvery surface is then capable of picking up the little particles of gold in the pulp and retaining them in the form of a coating of amalgam, which is naturally thickest where the pulp first comes upon the table. When a sufficient thickness has accumulated, the amalgam

is scraped off, which is mixed with a little fresh quicksilver, washed with water, and finally squeezed through canvas or chamois leather. The hard amalgam so obtained is distilled, and the spongy gold remaining in the retort is melted and cast into ingots. The mercury is condensed and used over again.

(18) Distillation.

It may be said that distillation is a purely physical process and consequently should have been dealt with under the previous section. This is true if one is dealing solely with the case of a change from the liquid into the gaseous state with subsequent condensation, but the most important instance of distillation at mines is not of this class. Coking is a process of distillation in which the application of heat creates sundry compounds which previously did not exist in the coal: the same may be said in the case of oil shale. Whether these processes of destructive distillation should be regarded as within or beyond the domain of the miner is a matter of opinion, they are so frequently carried on near the pit top and by the proprietor of the mine, that the student who is desirous of being acquainted with all the operations which a mining engineer sometimes has to superintend, cannot afford to ignore them

The commonest method of making coke is by bee-hive ovens. As the name tells us, these are ovens in the shape of the straw skep or hive for bees; they are about 11 to 12 ft. in diameter in the bottom and 7 ft. 6 in. to 8 ft. high. The floor is charged with a layer of coal about 5 ft. thick through a side opening which is afterwards built up; the warmth of the walls from a previous firing soon drives off gas which ignites when it gets into the flue. The top of the oven thus becomes filled with burning gas, and the heat so produced drives off more volatile matter; this in its turn burns, and the process goes on with increasing vigour until nothing is left behind but coke. The door is then pulled down and the coke raked out and quenched with water. In this old-fashioned process all the volatile matter is burnt and serves no useful process beyond furnishing heat, of which the supply obtained is more than sufficient. In order to utilise the constituents of the coal to greater advantage, coking is often performed in fire-brick retorts from which the volatile matter is led into appliances for collecting ammonia and naphtha. After these have been extracted, the residual gases are available for working gas engines. While admitting that the value of the products obtained is greater than with the bee-hive oven, the mine-owner

is often unwilling to abandon the old process, and for two reasons. First, the outlay for a new plant and the upkeep are considerable: and secondly, the coke is not so easily disposed of, as it lacks certain outward characteristics of the bee-hive oven product which purchasers regard as an index of quality.

Probably the prejudice against the newer form of coke will soon disappear in this country as it has done in Germany, and the bee-hive ovens will be superseded by the more economical retort-ovens.

Application of Processes.

The series of processes employed by the miner in preparing his produce for sale varies not only according to the nature of the particular mineral, but also according to the size of its particles

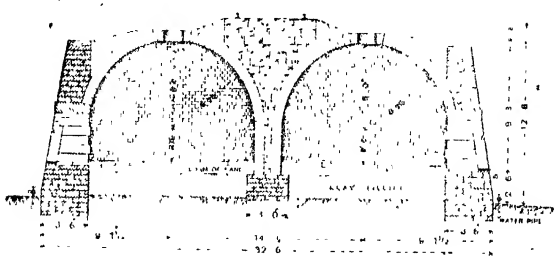


FIG. 269.—Beehive coke oven.*

and the nature of the other minerals with which it is associated. Space will not admit more than the briefest outline, nor is it necessary in an elementary work to enter into details.

Arsenic.—Arsenical pyrites, mixed it may be with tin or copper ore, is roasted in reverberatory furnaces, and the hot gases are conducted into brick chambers, the walls of which soon become coated with layers of solid arsenious acid. The crude arsenic resulting from the treatment of tin 'whits' is usually of a dirty grey colour owing to the admixture of solid carbonaceous particles deposited by the smoke; it is spoken of as 'arsenical soot,' and is sold by the miner to the works where it can be purified by being re-sublimated.

Coal.—The extent to which coal is prepared for the market

* Keighley, "Coke-making at the Oliver Coke-works," *Trans. Inst. M.E.*, vol. xxii., 1902, p. 493.

varies greatly. The product of the mine may be ready for sale after it has simply passed over a screen to take out the small: and on the other hand, if intermingled with much shale or pyrites it may require to undergo an elaborate series of crushing and washing processes to fit it either for sale, the coking oven, or the briquetting plant. The brown coal of Germany, containing about 50 per cent of water, has to be dried in special kilns before being sent to the briquetting presses.

Anthracite dressing is merely an elaborate system of screening after the shale has been picked out.

Copper Ore.—Copper ores are treated by crushing in rolls or stamps, sizing by trommels, and then jigging and buddling; in the case of some of the ores which are very friable and easily carried away by water, hand-picking is employed to a greater extent than with lead and tin ores, and the enrichment by water is not carried so far on account of the inevitable loss that would ensue. The amount of concentration depends upon the distance from the smelting works, and the mine-owner has to calculate whether it is better to get a low price for a large quantity of ore, after paying the carriage, or a higher price for a small lot, when due allowance has been made for the cost of dressing and the loss sustained in that process.

Diamonds.—The dressing of the diamond-bearing rock of South Africa may be divided into the following separate operations:—

a. Natural disintegration under atmospheric agencies, aided by watering, rolling, and harrowing.

b. Screening in a revolving screen, with holes 1 inch by 1 inch, or 1 inch by $1\frac{1}{4}$, which takes out coarse lumps; these are returned to the depositing floors to undergo the weathering process a little longer.

c. Washing the fine in rotary pans, which separates clean gravel from the fine sand and mud; the latter flow into another similar washer, where the process is repeated in case any diamonds should have escaped in the overflow from the first.

d. Preparing the clean gravel for the 'pulsators' by dividing it into five sizes by means of a suitable cylindrical sieve. The largest grains discarded by the sieve are picked over at once.

e. Treatment in a 'pulsator,' which is simply a jig with continuous feed and discharge like the Hartz jigs. The bed is formed of leaden bullets. A concentrate, containing the diamonds, passes through the bed, and refuse goes over the edge of the jig.

f. Picking out the diamonds by hand. If the concentrate is

passed over grease tables, a considerable amount of hand-picking is saved.

Gold.—The precious metal may be extracted from simple sand and gravel by adding water and allowing the stream to run along specially designed troughs with or without mercury. When gold is enclosed in hard rock, such as quartz, or occurs in a hard conglomerate, the auriferous stone has to be crushed in order to set the metal free.

The crushing is mostly effected by stone-breakers and stamps, and much of the metal is then caught by passing the pulp over amalgamated copper plates; what escapes is passed through classifiers, and the various products are commonly treated by the cyanide process. The gold may also be extracted from the concentrates by chlorination.

Iron.—With a substance of small intrinsic value like iron ore, the methods of dressing must be inexpensive if they are to be commercially profitable; and it may be said that most of the iron of to-day is obtained from ores which go direct to the smelter without any preparation beyond picking out the refuse by hand at the mine or quarry. Calcination, as already noted, is employed in the case of the carbonate. Iron ore is sometimes washed in order to get rid of adherent clay, and at the mines of North Lancashire some of the haematite, mixed with clay and siliceous matter, is made fit for the blast furnace by crushing and jigging.

In this country the supply of magnetic iron is insignificant, and consequently we cannot show examples of concentrating by the aid of magnetism, such as may be found in Sweden and in the United States, where the method is occupying much attention.

Lead.—Much of the lead ore from veins is dressed by crushing, sizing, and jigging; the particles under 1 mm., or at all events under $\frac{1}{2}$ mm., are treated by revolving tables, percussion tables, endless belts, or buddles.

The crushing is done first by a stone breaker and then by rolls. The crushed ore is classified by revolving screens and the resulting grains are concentrated by jigging. Particles of ore with adherent matrix must be re-crushed, sized, and jigged. The finer sizes are classified by pyramidal boxes and concentrated by frames, rotating tables, and buddles.

Phosphate of Lime.—The varieties of this mineral are so numerous, from the hard compact apatite of Canada to the pulverulent mineral from the Somme district, that the modes of treatment must necessarily be extremely different. Very often there is merely a preliminary washing, followed by drying and grinding; the finely-ground mineral is then put up into sacks

ready for the farmer. In other cases the miner satisfies himself with removing all waste, and leaves to other persons such processes as milling or manufacture into superphosphate.

Quicksilver.—The great intrinsic value of quicksilver ore enables hand picking to be carried on further than would be compatible with a mineral of little worth. At Idria the loss of mercury was so great under the old system of wet dressing, in spite of the high specific gravity of cinnabar, that this method was given up some fifty years ago. Nowadays, the preparation for smelting is done solely by crushing, sizing, and hand-picking.

Salt.—Rock salt may be sold without any treatment, or may be prepared for the market by crushing; a saleable product is obtained from brine by simple evaporation.

Silver.—The ores of silver may be divided into two classes—silver ores proper and argentiferous lead and copper ores.

Many of the silver minerals are very friable, and are liable to be carried off with the refuse, if subjected to the ordinary wet dressing processes; the preparation of such ores at the mine is generally limited to crushing, picking, and cobbing. The miner then relegates to others the task of extracting the precious metal by methods based upon its affinity for quicksilver or molten lead, or upon the leaching properties of certain salts.

Argentiferous lead and copper ores are concentrated by the processes in vogue for the baser metals; if the proportion of silver is large, a greater amount of labour may be expended upon hand-picking and cobbing than would be permissible with ores of lead and copper alone.

Slate.—Two articles of commerce are made at the quarries: roofing-slates and thick slabs used for cisterns, billiard tables, and tombstones. The slate arrives at the surface in the form of large blocks, often weighing two tons or more. These are divided by splitting into slabs about 3 in. thick, which go to the sawing tables. The circular saws cut up the slabs into pieces suitable for the operation of fine splitting; by the careful and dexterous uses of his wedge and mallet, the quarryman is able to split the slab into thin sheets, which at Festiniog often do not exceed [illegible] in. in thickness. These have to be trimmed, generally into a rectangular form. Though this operation can be, and often is, performed by hand, it is more common to use some kind of knife worked by machinery. The slates are then sorted by hand according to their quality.

The slabs are first split out of blocks, and are finished by being sawn into shape and planed smooth by machinery.

Stone. It is impossible in an elementary treatise to enter into any details concerning the preparation of stone at mines and quarries. Some stone is shaped by hammering into paving blocks or 'setts'; much is crushed by stone-breakers and sold as road metal after removal of the fine by screening; freestone is sawn so as to suit the builder; flags are obtained by splitting micaceous sandstone along the planes of bedding and trimming the edges; and, lastly, gunflints are made from the well known nodules by the dexterous chipping of the 'knapper.'

Sulphur.—This element is obtained from the rock, which contains it in the native state, by simple liquation in a kiln of some kind, intermittent (*calcarone*) or continuous (Gill's furnace), or by liquation in steam-heated cylinders, or occasionally by distillation in iron retorts: this last process, which was at one time practised with rich ore in the Romagna, is now almost entirely abandoned.

Tin.—Tin bearing rock is crushed by the stone-breaker and then stamped fine. The pulp is run over Frue Vanners, which furnish a preliminary concentrate (*whits*) containing the tin ore mixed with iron pyrites and arsenical pyrites if these minerals are present in the rock. Roasting in a furnace converts the heavy sulphides into pulverulent oxides, which are easily got rid of with the rest of the waste by buddling and framing. Alluvial tin ore is concentrated in sluice-boxes and sometimes by jiggers, after a preliminary treatment in a puddling machine, if there are balls of clay which have to be broken up.

Zinc.—Calamine has sometimes to be washed, in order to rid it of clay, before it is crushed and jigged like lead ore. Blende is dressed in the same way as lead ore, and is often obtained from one compartment or portion of a dressing machine, whilst galena is being discharged from another.

CHAPTER XIV.

LEGISLATION.

It may appear strange to some persons that the elementary student should be troubled with law. My reason for giving a short chapter upon legislation is that mining differs from most other occupations by being regulated by special statutes, and that it is especially with an uncongenial branch of the subject like law that the student needs a helping hand.

I propose to deal with the subject very briefly in the following manner.—

(1) Classification of mineral workings in the United Kingdom.
(2) Statutes relating solely to mines and quarries.
(3) Certain statutes affecting mines and quarries incidentally.

(1) Classification of mineral workings in the United Kingdom.

In the eyes of the law there are two principal kinds of mineral workings in the United Kingdom, viz., mines and quarries. The former are workings which are carried on underground, in other words, under cover of earth or rock, whilst the latter are workings open to the sky. It is consequently the nature of the excavation, and not the nature of the mineral, which determines, from a legal point of view, the class into which any given workings are placed, no matter what their name may be in popular parlance.

Thus underground workings for slate and stone are legally 'mines' and not quarries, though generally called by the latter name, whilst open workings for iron ore are legally 'quarries' and not mines. It is important to grasp this fundamental fact, because in other countries the distinction between mine and quarry may be based upon totally different grounds. What is legally a 'mine' in this country, may legally be a 'quarry' in France, and *vice versa.*

But even in this country it is not every underground working

which is legally a mine, nor is every open working legally a quarry. The purpose of the excavation has to be taken into account. Underground passages constructed for railway trains, for sewage purposes or for waterworks, are not considered mines legally, because they are not made with the object of getting minerals; again, a railway cutting though open to the sky is not legally a quarry while it is being excavated, because it is dug out in order to make a road for trains. And even if the spoil from a railway tunnel or cutting is utilised for the purpose of constructing an embankment or even for making bricks, the working still fails to be a mine or a quarry, because the primary object of the excavation, *i.e.*, getting minerals or not getting minerals, is the criterion which settles whether it is to be subject to or exempted from the statutes relating to mines and quarries.

We thus arrive at these two definitions:—A mine is a place underground where persons work for the purpose of getting minerals; a quarry is a place open to the sky where persons work for the purpose of getting minerals.

There is a third kind of mineral working in this country, viz., the well or borehole for obtaining brine or natural gas.

The complete classification of mineral workings for legal purposes in the United Kingdom is as follows:—

(*a*) Mines.
(*b*) Quarries.
(*c*) Wells and boreholes.

(2) Statutes relating solely to mines and quarries.

There is no special law regulating the working of wells and boreholes, so I here have to deal solely with mines and quarries. Want of space forbids my writing even a brief history of mining legislation in this country; suffice it to say that during the last half-century a number of statutes have been passed by Parliament with the object of lessening the dangers of the miner's occupation, which appears to the general public to be extremely hazardous. How far this is really the case is a matter to be dealt with in the next chapter.

There are two principal Acts of Parliament regulating the working of mines in the United Kingdom*—the Coal Mines Regulation Act, 1887, and the Metalliferous Mines Regulation Act, 1872.† The former applies to workings for coal, stratified

* Together with the Isle of Man, which as a rule is not affected by Acts of Parliament passed at Westminster.

† The full text of each of these Acts, and of others which will be mentioned later, can be obtained for a few pence from the King's printers, Messrs Eyre & Spottiswoode, East Harding Street, Fleet Street, London, E.C.

ironstone, fire-clay, and shale, the latter applies to all workings not included by the former. Every mine must therefore be under one or the other of these two Acts. It is well to point out that the titles of the Acts are decidedly misleading. The Coal Mines Regulation Act applies to the great iron mines of the Cleveland district, because the ore occurs as a *stratified* deposit; the Metalliferous Mines Regulation Act applies not only to all copper, lead, and tin mines, but also to numerous underground excavations for stone, slate, etc. In other words, the Coal Mines Act regulates certain large ore mines whilst the Metalliferous Act includes workings for substances which are not metallic ores.

I will now take each of the two classes of mines separately and then deal with quarries.

(*a*) *Mines of coal, stratified ironstone, fire clay, and shale.* The principal statute as already mentioned, is the Coal Mines Regulation Act of 1887; this is supplemented by the Coal Mines (Check Weigher) Act, 1894, the Coal Mines Regulation Act, 1896, and the Coal Mines Regulation Act (1887) Amendment Act, 1903.

The principal Act relates to various matters, of which the following are the most important, viz., employment of women and children, certificated managers, mine plans, outlets, working regulations.

Females may not be employed below ground. Mines in which more than thirty persons are employed below ground must be in the charge of a manager possessing a certificate granted by a Board for Examination, established in a manner prescribed by the Act. There must be two outlets to every mine, save in the case of workings employing fewer than thirty persons below ground.

The working regulations are known as General Rules. These are thirty-nine in number, and deal with ventilation, timbering, use of explosives, safety-lamps, inclined planes, travelling roads, fittings for steam boilers, fencing machinery and inspection by the workmen. The General Rules apply to every mine.

Recognising the fact that further regulations would be desirable and that the conditions of the various mining districts are not the same, Parliament made provision for the establishment of what are called 'Special Rules', when once established with all the prescribed formalities, these Special Rules have the same force as the General Rules. To secure obedience, breaches of the rules, and of the Act generally, are punishable by heavy money fines, or even imprisonment.

The Coal Mines (Check Weigher) Act of 1894 makes it penal to interfere improperly with the appointment of check weighers,

and the amending Act of 1896 makes further regulations concerning mine plans and safety-lamps, and gives the Secretary of State powers to forbid the use of explosives which he may consider unsafe. A testing station has been erected by the Home Department, and lists of the explosives which have satisfied the authorities are issued from time to time.

The Mines (Prohibition of Child Labour Underground) Act, 1900, forbids the employment below ground of boys under thirteen years of age, and applies to all classes of mines.

The Coal Mines Regulation Act (1887) Amendment Act, 1903, allows the mining diploma of a University or Mining School, approved by the Secretary of State, to be reckoned as the equivalent of two years' experience in a mine. Therefore the graduate can obtain a manager's certificate after having had practical experience in a mine for three years; a five years' experience is necessary for a candidate who has no diploma.

(*b*) *Mines of copper, lead, tin, and zinc ores, unstratified iron ore, gypsum, salt, slate, stone, etc.*—The Metalliferous Mines Act, 1872, though framed after the fashion of a sister Act, the Coal Mines Regulation Act of 1872, now repealed, is very far from being so stringent or so useful as that statute. Persons engaged in getting ores and stones are allowed a freedom which has long been denied to coal miners, although the latter have the safer occupation, as will be shown in Chapter XVI.

No certificated managers are required; there are only nineteen General Rules, and the establishment of Special Rules is not compulsory.

The amending Acts of 1875 and 1891 deal with points of detail, and the Slate Mines (Gunpowder) Act, 1882, gives power to the Secretary of State to exempt slate mines from certain regulations relating to the use of explosives.

(*c*) *Quarries.*—The Quarries Act was passed in 1894. It defines a quarry as "a place, not being a mine, in which persons work for getting clay, stone, sand, coprolites, or any other kind of minerals." The Act applies to all quarries which are more than 20 feet deep, but does not touch those which are below that depth.

It imposes very few obligations upon the quarry-owner. He is merely bidden to post up an abstract of the Act, and to send in an annual return of persons employed and mineral raised. There are no working regulations whatever. However, there is power to establish Special Rules, and a fairly uniform code of regulations has been established at the majority of the quarries of the kingdom. These regulations are established in order to prevent accidents.

The Quarry (Fencing) Act of 1887 was passed in order to protect the public from accidentally falling into quarries near thoroughfares.

The present state of mining and quarrying legislation is summed up in the following table:—

Kind of Working.	Kind of Mineral Worked.	Special Statutes regulating the Workings.
Mines	Coal, stratified iron stone, fire clay, and shale	Coal Mines Regulation Act, 1887. Coal Mines (Check Weigher) Act, 1894. Coal Mines Regulation Act, 1896. Mines (Prohibition of Child Labour Underground) Act, 1900. Coal Mines Regulation Act (1887) Amendment Act, 1903.
	All minerals not included by the Coal Mines Regulation Act, such as the ores of copper, iron (unstratified), lead, tin, and zinc, gypsum, salt, slate, stone, etc.	Metalliferous Mines Regulation Act, 1872. Metalliferous Mines Regulation Act, 1875. Slate Mines (Gunpowder) Act, 1882. Metalliferous Mines (Isle of Man) Act, 1891. Mines (Prohibition of Child Labour Underground) Act, 1900.
Quarries more than 20 feet deep.	Any mineral.	Quarries Act, 1894.
Quarries less than 20 feet deep.	Any mineral.	No special Statute.
Wells and bore-holes.	Brine and natural gas.	No special Statute.

(3) Certain Statutes affecting Mines and Quarries incidentally.

Several other Acts of Parliament affect the extraction of minerals or their preparation for the market. I will mention the most important and take them in alphabetical order.

Alkali, etc., Works Regulation Act, 1881 and 1892.—These titles, like many others, are misleading, because the province of the statutes extends far beyond soda-making establishments. The object of the Acts is to prevent the escape of noxious fumes,

and they are made to apply to cement works, which are often directly connected with chalk quarries, to salt works, to places where arsenical ores are roasted, and to collieries where tar and ammoniacal liquor, obtained from the waste gases of coke ovens, are being treated. The Acts are enforced by inspectors appointed by the Local Government Board.

Boiler Explosion Acts, 1882 and 1890.—It is the duty of the mine-owner to report to the Board of Trade any boiler explosion which happens on his premises. The Board is empowered to hold inquiries concerning boiler explosions, and indirectly to inflict severe penalties upon negligent owners or agents by causing them, without any chance of appeal, "to contribute towards the expenses of the inquiry." Whilst the Mines Regulation Acts, and Factory and Workshop Act lay down plain rules for avoiding accidents and are therefore directly preventive, the Boiler Explosion Acts give no hint concerning desirable precautions and are only indirectly preventive.

Brine Pumping (Compensation for Subsidence) Act, 1891.—The extraction of brine in Cheshire causes frequent and considerable subsidences of the adjacent land. Where pumping is being carried on by several firms in a district, it is impossible to say which has been the cause of a given subsidence, and the burden of compensation has very fairly to be borne by all brine pumpers. Each one now pays his share according to the quantity of brine he raises.

Explosives Act, 1875.—This Act deals with the manufacture, sale, transport, and storing of explosives. It affects the mine-owner inasmuch as he has to obtain a licence from the Local Authorities for storing explosives, and has to build and keep his magazine in conformity with certain regulations. The Act has to be enforced by the Local Authorities, who usually employ their police to do the work, and also by the inspectors of Explosives appointed by the Home Office.

Factory and Workshop Act, 1901.—The object of this Act is to secure the health and safety of persons employed at factories and workshops. Its most important provisions are those which deal with sanitation, the working hours and meal-times of women, young persons and children, and the fencing of machinery. Quarries and the dressing floors of mines under the Metalliferous Act are legally factories or workshops, and the provisions of the Factory and Workshop Act are enforced by the Inspectors of Mines, who have been appointed Inspectors of Factories.

On the other hand, coal screening and coal washing works adjacent to collieries and belonging to colliery companies are

not under the Factory and Workshop Act, as the employment of protected persons, *i.e.*, women, young persons, and children, is already dealt with by the Coal Mines Regulation Act.

Rivers Pollution Prevention Act, 1876.—Speaking broadly, the discharge of mine refuse into rivers is undesirable; but if the mine-owner does turn it into a stream, the Act compels him to take the best practicable and reasonably available means to render it harmless. In a few cases it has been admitted that the mining interest is of more importance than any other, and the tin mines near Camborne and Redruth are allowed to discharge their tailings into sundry small brooks without let or hindrance. Tin ore to the value of upwards of £30,000 is recovered yearly from the mine waste as it flows down to the sea.

Truck Acts, 1831, 1887, and 1896.—The evils of the 'Tommy shop' in olden days have been well depicted in Disraeli's *Sybil*. These abuses have been swept away, and miners, together with other workmen, are entitled to receive their full wages in coin of the realm without deductions other than those to which they have agreed.

Workmen's Compensation Act, 1897.—This statute compels the employer to compensate a workman in his employ who is injured by accident, or to compensate the dependent relatives in case the workman is killed. No compensation is paid to injured men until they have been laid up for at least a fortnight.

CHAPTER XV.

CONDITION OF THE WORKMEN.

THE matters dealt with in this chapter may be regarded by some persons as superfluous, or at all events as out of place in an elementary text-book, and it is likely that they will ask the question, "Why should the young mining student be troubled with problems which are left untouched in large treatises upon engineering?"

My reply is that the labour question is of so much importance that the student should have his attention directed to it at the very outset of his career. We may talk about the use of labour-saving appliances, about the substitution of machinery for human hands, but after all what is the dominant factor in the cost-sheets of mining undertakings? Both at home and abroad the answer is: Labour.

The following figures lately compiled by Mr D. A. Thomas, M.P.,* from the accounts of three large steam-coal collieries in South Wales, show that speaking roughly four-fifths of the expenditure in getting and raising coal is due to labour.

Percentages of total cost of production of large coal at the pit's mouth.

Item.	1897.	1900.
Labour	77·98	81·72
Stores and materials	12·67	11·87
Royalties	6·64	4·38
Rent, rates, etc.	2·57	1·84
Incidentals	0·14	0·19
	100·00	100·00

* "The growth and direction of our foreign trade in coal-mining during the last half-century," *Jour. Stat. Soc.*, Sept. 1903.

The first year was chosen as a year of low wages, and the second as one of high wages.

In the gold and coal mines of the Rand, according to the figures lately prepared by the Johannesburg engineers,* the main items of expenditure are for labour, explosives, and coal, and in the following proportions: Labour, 60·07 per cent. of the total cost; explosives, 14·85 per cent.; and coal, 8·20 per cent.

If, then, so large a proportion of the cost of getting minerals is spent upon wages, surely it behoves the teacher to point out the fact even to elementary students and to say something about the suppliers of muscular force.

From purely philanthropic motives, the employer will wish to keep his workpeople *healthy, happy, contented,* and *comfortable*, and from the lower plane of commercial expediency it will pay him to do this, for if it appears in the course of time that the occupation brings disease and shortens life, the rate of wages will have to rise in order to tempt persons to adopt it.

And further, in the case of mining, the labour question often assumes aspects which may be entirely absent in other occupations. Workable mineral deposits are frequently discovered in out-of-the-way and thinly-populated parts of old and new countries, and the mining engineer, perhaps more than most other employers, is obliged to face the task of collecting workmen, housing them, teaching them a new trade, and looking after them generally.

In a word, it may be safely said that the labour problem is often more difficult to solve than that of merely wresting the mineral from the earth's crust.

The matters which I propose to discuss very briefly in this chapter are the following: (1) Conditions of Labour, (2) Clothing; (3) Housing; (4) Occupational Diseases; (5) Hospitals, (6) Education; (7) Recreation.

(1) Conditions of Labour.

In many cases the miner is merely a unit in the working population of a district, living it may be in a cottage next door to an agricultural labourer or a factory hand, but differing from them by the fact that his work is carried on below ground. He toils in tunnels, pits, and chambers in which there is no sunlight, where the air is apt to be polluted by all sorts of impurities, and where the heat is sometimes great. Lastly, I may add that in pursuit of mineral treasures men are tempted to dwell

* "Statistical statement of the gold-mining industry of the Witwatersrand," *The Transvaal Leader*, 16th Jan. 1903, p. 9.

at great elevations among the mountains, or in malarial valleys, or in hot and thirsty deserts, or amid Arctic frosts and snow, and consequently the trying effects of high altitudes, of heat and cold, of fever and other diseases, must therefore occasionally be reckoned among the drawbacks attending the miner's occupation.

While recognising to the fullest extent the value of the vivifying and germicidal qualities of the sun's rays, I am not aware that it can be asserted, without fear of contradiction, that the miner suffers to any marked extent from having to toil many hours a day by artificial light. On the other hand, it will be shown immediately that he is often seriously affected by having to breathe an impure and dust-laden atmosphere. With reference to the temperature of the air in working-places below ground, it may safely be stated that the heat is not usually excessive; at the present time in this country it rarely rises to 90° F. (32° C.). The warmth is due to various causes, viz., the internal heat of the earth, the oxidation of minerals, such as coal, iron pyrites, spathose iron, etc., and lastly to the issue of hot mineral waters. On the Comstock lode in Nevada,* the miner was troubled by hot springs with temperatures reaching even 170° F. (76°·6 C.), and the discomfort of the heated moist atmosphere was very great. In dealing with the frozen gold-bearing gravels in Arctic regions, and again while sinking shafts by the Poetsch process, the miner is surrounded by walls of icy rock, but in the comparatively still atmosphere of the mine he suffers no inconvenience.

It must be pointed out that working underground has its compensations; the miner during his work is not exposed to rain, nor to the pitiless sun of the tropics, nor to the icy blasts of a northern winter; he is usually able to work all the year round in an equable and not disagreeable temperature. However, it should be remembered that many persons called miners are engaged in quarrying ore or fuel in pits open to the sky, and that they are consequently earning their livelihood under conditions which, as far as light, air, and warmth are concerned, are identical with those pertaining to the farming industry.

The troubles due to locality are often real. Those who have ascended high mountains and who have experienced the unpleasant symptoms caused by a highly rarefied atmosphere may wonder how such hard work as mining can be carried on at altitudes of 15,000 feet and more; no doubt natives who have lived from

* Lord, "Comstock Mining and Miners," *Monographs U.S. Geol. Survey*, Washington, 1883, p. 391 *et seq.*

childhood in such regions are exempt from ills which affect the newcomer from the plains, but, nevertheless, they appear to die early, owing to the elevation at which they dwell.

Without wishing to minimise the dangers of some fever stricken districts, I cannot help remarking that tales about unhealthy climates must sometimes be taken with a large grain of salt. If the real truth were known, the attacks of the so called 'fever' would occasionally turn out to be due rather to excess or imprudence of the traveller himself, than to unhealthiness of the country.

(2) Clothing

The underground worker requires suitable clothing, but not for precisely the same reasons as the labourer on the surface. The main object of the miner's hat or cap is to protect his head from knocks, and not to keep off the sun or rain. The temperature of the working place is often high enough to enable even the European to strip to the waist, and so obtain a freedom of limb eminently conducive to effective muscular work, to say nothing of the advantage of the direct contact of the perspiring skin with the atmosphere, a comfort little known to the average English man, who is rarely able or willing to discard all clothing and roam about like a savage. Strong foot gear is often desirable as a protection against blows from stones which tumble about during the processes of getting the mineral or loading it into waggons.

Many workmen keep a special suit of working clothes at the mine itself, don it before going underground, and then exchange it for ordinary attire before returning home. This practice should be encouraged, as it is far better for the miner to change his clothes at the mine than at home, where it is not easy to have all the conveniences for ablutions and for drying the damp or dripping garments worn underground. Many mines, and especially the modern collieries of France and Germany, have most excellent changing-houses fitted up with washing basins and warm shower-baths. Various arrangements are adopted for preventing the theft of the suits of clothes which have to be left in the building. A common plan is to provide for each miner a chain which passes from a little winch over a pulley near the roof and terminates in a set of hooks. The clothes are hooked on and the chain is wound up till they are well out of reach; the miner now locks the winch with a key which he carries. Warm air is made to circulate through the building, and wet clothes are thoroughly dried before the beginning of the next shift.

(3) Houses.

Accommodation may be required for various classes of workmen, viz., married men living on the spot with their wives and families; married men whose wives and families live at a distance, and, thirdly, bachelors. Occasionally the 'compound' system is adopted, under which the workmen voluntarily submit to be kept under lock and key for a certain number of months, and lastly, must be mentioned the plan of employing convicts, who are housed in prisons and marched to and from their work under the care of warders

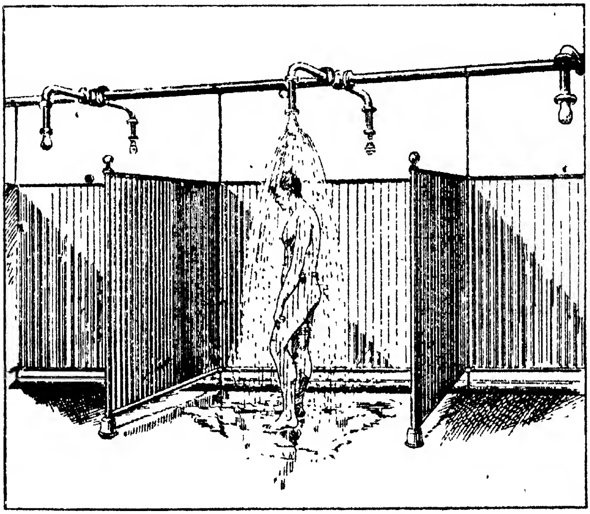


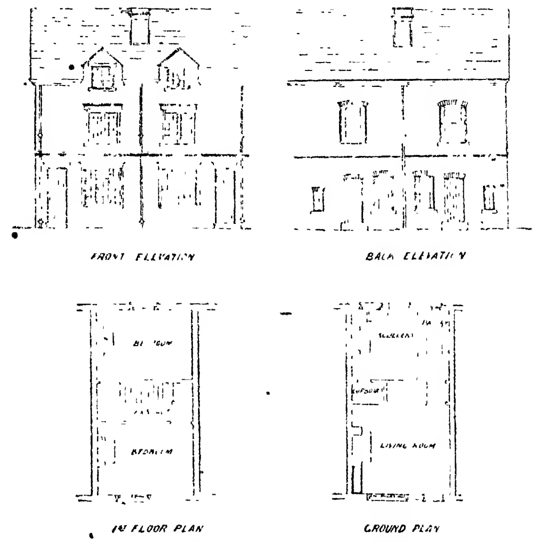
FIG. 270.- Shower baths at the Anzin Collieries, France.

For housing the three first classes of workmen many mining companies in all parts of the world have built extensive villages, and as time goes on the class of cottage is gradually being improved. I was pleased to find not long ago in North Wales that some new cottages for quarrymen were all provided with bathrooms. A garden for each cottage is very desirable.

Bachelors and married men from distant homes may find quarters in the houses of married couples or in barracks; these

are sometimes erected on a palatial scale, and are provided at extremely reasonable prices with all sorts of conveniences for the inmates. They are in reality comfortable residential clubs for workmen.

The 'compound' system has been carried out on the largest scale at the Kimberley diamond mines, South Africa, where it was introduced for the purpose of preventing the robbery of valuable



FIGS. 271, 272, 273, and 274.—Miners' cottages, Bolsover Collieries, Nottinghamshire.

gems by the Kaffir labourers. They hire themselves out for periods varying from three to six months, and during their engagement must never leave the Company's premises. When not actually at work they are confined in the 'compound,' which is a settlement, surrounded by an unclimbable fence and carefully guarded, with separate living houses for the various tribes, a big swimming-bath, and a store for supplying food, raiment, and luxuries.

(1) Occupational Diseases.

Each industrial occupation may be said to involve certain risks to health, sometimes extremely slight, sometimes decidedly marked. Phosphorus poisoning among the match makers, lead poisoning among painters and potters using the old-fashioned glazes, and anthrax among persons handling hides, are cases in point; and in like manner mining carries with it special dangers to health, wholly apart from accidents.

Probably the worst enemy of the miner is dust; and in making this statement I am thinking not merely of the disastrous explosions in which coal-dust has played a leading part but also of the dire effects of mineral dust taken in through the mouth or nose and finding its way into the lungs or into the stomach. Its action may be mechanical or chemical, and the former is the more common. Particles of dust drawn into the lungs with the breath stick to the mucous membrane and set up an irritation, which does not cease so long as the man continues to work in the impure atmosphere. The miner eventually succumbs either to 'silicosis' pure and simple, often called 'miner's phthisis,'* or to the same malady with tubercular consumption added to give the *coup de grâce*. In the former case the air passages become so irritated by the angular particles that the lung tissue undergoes a gradual change and is rendered incapable of carrying out its proper functions; in the latter, the stone dust, while producing the same changes, paves the way for true tuberculosis by reducing the germ resisting power of the lungs, and making them unable to fight the attacks of the tubercle bacillus.† The harder and sharper the dust, the worse seem to be its effects. The persons most exposed to danger are those who are working percussive machine drills in hard siliceous rock, and the great dustiness of the atmosphere will be quickly recognised by any one dressed in a dark suit who stands by the side of one of these machines in operation. The mortality from silicosis on the Rand, especially among the rock drill men, has been appalling.

The first remedy which naturally suggests itself is the prevention of dust by introducing water into the hole during the process of boring. When the hole is pointing downwards the matter is easy; if it is inclined upwards, a jet of water, produced either by a fall down a pipe or by compressed air taken from the main, may be squirted in with useful though not always entirely success-

* *Report of the Miners' Phthisis Commission*, Pretoria, 1903, p. 4.

† Legge, "Dust from Ganister and Fire-resisting Materials," *Ann. Rep. Chief Inspector of Factories and Workshops for the year* 1900. London, 1901 [Cd. 668], p. 481 *et seq.*

ful results, because when the hole is deep the water may fail to penetrate to the very bottom. Bornet * of Paris has introduced the ingenious flushing arrangements shown in figure 275.

A B is the piston rod prolonged to form the tool-holder, and C D is the striking chisel or drill. E F is a box attached to the cylinder of the machine, with a brass lining G H surrounding the piston rod; the lining has a long annular groove forming a space into which water is constantly forced from a hose screwed on at E. J K L is a long central passage in the piston rod, leading into a similar hole L M in the drill. As long as J is travelling between N and O, water runs from J to M, and flushes out the chips and powder formed by the blows of the chisel edge D upon the bottom of the hole. P and Q are leather washers.

The flushing serves not only to prevent the dust, but also to improve the action of the tool by the immediate removal of all the chippings. Practical work at the Anzin collieries has proved that holes are bored more rapidly with Bornet's appliance than without.

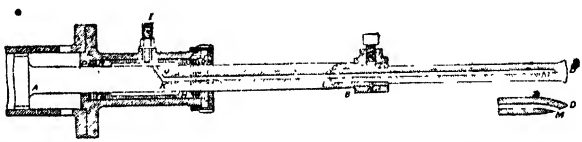


FIG. 275.—Bornet's arrangement for flushing bore-holes.

The invention commends itself, therefore, by combining increased efficiency with better hygienic conditions: the appliance can be fitted at a very small cost to any percussive boring machine whether driven by compressed air or electricity.

One advantage of Brandt's rotary hydraulic drill is the absence of dust, and the same may be said of the Water Leyner Drill.

A second means of combating silicosis is to use a spray of some kind to keep the dust down in the working places, and a third plan is wearing a respirator.

In addition to the mechanical effect of dust, its chemical action has to be considered in a few special cases. Where ores contain carbonate of lead, the workmen are liable to suffer from plumbism in the same way as painters; the poisonous mineral is taken into the system from handling food with dirty hands. Probably lead poisoning was never so rife at any mines as at Broken

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1899, London, 1900 [Cd. 373], p. 101.

Hill, N.S.W., a few years ago, when a soft, pulverulent ore containing cerussite was being extracted. Men engaged in mining galena do not suffer, because the ore is insoluble and passes out of the bowels unchanged. Cinnabar mining carries with it the risk of mercurial poisoning, and the dust of arsenical cobalt and nickel ores is considered by doctors to have been the cause of cases of cancer at certain mines in Saxony.

On the other hand, some writers are ready to credit coal dust with beneficent effects, and ascribe the comparatively low death-rate of coal miners from tubercular consumption to antiseptic properties possessed by the dust, which is supposed to check or prevent the growth of the tubercle bacillus. I am not aware that this explanation is universally accepted by the medical profession, whilst the evil of clogging the lung passages with any dust seems certain. As a layman I may suggest that the partial immunity of the coal-hewer from tubercular consumption may be due to the fact that, owing to the progress of his work, he is constantly having new, fresh, and unpolluted surroundings. The sputum of a consumptive comrade will soon be buried in the goaf and rendered harmless, whereas saliva discharged on to the floor of a factory is likely to be wafted about after drying up and become a source of infection.

Some colliers suffer from nystagmus, a disease which makes objects appear to dance before the patient when he looks at them. The malady is due to overstraining the muscles of the eye; two causes have been suggested to account for it, first, the poor light of the safety lamp, and, secondly, the recumbent posture of the hewer, which makes him turn his eyes in an unnatural manner while endeavouring to guide the blows of his pick.

The disease known as miner's anæmia, or ankylostomiasis, has given much trouble of late years on the Continent, and has lately been recognised by Dr Haldane, F.R.S., among workmen at Dolcoath tin mine in Cornwall.* It is due to the presence of small worms, like pieces of white thread and ¼ to ¾ inch long, which hook themselves on to the mucous membrane of the intestines; when their number has to be reckoned by hundreds, it is not surprising that they cause great disturbances in the system, which may even result in death. The female lays eggs which pass out with the fæces of the person attacked; if the conditions are favourable—that is to say, if there is warmth, moisture, and darkness—the larvæ hatch out, and mud in the

* *Report to the Secretary of State for the Home Department on an Outbreak of Ankylostomiasis in a Cornish Mine*, London, 1902 [Cd. 1318.]

mine may swarm with them. A miner may then easily become infected from one upon his hands, which happen to touch his food, mouth, or skin. Mere contact with a sufferer will not communicate the disease.

The malady is troublesome; but when once discovered it is, easily cured by the administration of thymol or the extract of male fern. It may fairly be called an occupational disease among miners in northern countries, because in our climate the conditions necessary for the hatching of the eggs, the development, and the spreading about of the larvæ, would rarely exist above ground. As a matter of fact, the wives and children of miners in Europe are not attacked. The disease may be prevented from spreading by making the men void their excreta into pails underground; the evacuations should then be disinfected and the pails emptied at the surface.* It has lately been pointed out † that the introduction of watering into Westphalian collieries, for the purpose of keeping down coal-dust, has been followed by a very great increase in the number of cases of ankylostomiasis.

In studying the diseases of any industrial population, care must be taken to distinguish between those which are truly occupational and those which are not necessarily connected with it. Thus we are told that, as a class, the Festiniog slate miners suffer from indigestion and from pneumonia.‡ According to medical evidence, the former ailment is largely due to drinking badly brewed tea, whilst the latter is apt to affect those who sit in their damp clothes while travelling home by train.

(5) Hospitals.

Both at home and abroad, large mining companies often establish and support hospitals for the benefit of any of their workmen who may require medical aid on account of accidents or disease, and it is pleasing to note that the prejudice formerly felt by the working classes against these useful institutions is rapidly disappearing. Of their value there can be no question. The patient is placed in surroundings far more conducive to his recovery than those of his home, no matter how tender; he has the needful quiet, more frequent medical attendance, better

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1899, London, 1900, p. 352. [Cd. 447.]

† "Ueber die Massnahmen zur Bekampfung der Wurmkrankheit auf den Zechen des Ruhrbezirkes," *Gluckauf*, vol. xxxviii., 1902, p. 1249.

‡ *Report of the Departmental Committee upon Merionethshire Slate Mines*, p. xxi., London, 1895. [Cd. 7692.]

nursing, and more suitable diet. It may here be remarked incidentally, that the surgeons attached to hospitals connected with mines and quarries often become extremely skilful in treating the special classes of accidents due to the occupation, and enjoy a well deserved reputation in their profession.

(6) Education and Religion.

It is not only in the case of the sick and injured that a mining company may have its obligations. The shareholders may feel that after having gathered together a number of workmen to form a community, it behoves them to make provision for the education of the young and the spiritual needs of all. Schools are frequently kept up and ministers of religion provided, solely at the expense of a large mining company, and in other cases substantial aid is afforded. Primary education may well be followed by a certain amount of technical training for bright lads and young men desirous of becoming foremen, and it is wise not to forget the girls, who should be taught cooking, sewing, and other domestic arts.

(7) Recreation.

The philanthropic employer will not rest content, even if he has provided cottages, hospitals, schools, and churches. Supposing the workmen to spend eight to ten hours in the mine, and eight hours in sleep, there still remain six or eight hours for meals, rest, and recreation. From a purely business point of view, it is to the employer's interest that the kinds of recreation should be of a nature to do the workmen good and not harm. Consequently, without trying to exercise too strict and parental a control, which would certainly be resented, the employer can do good by endeavouring to direct the amusements into proper channels; he has the opportunity of encouraging games, music, gardening, reading, etc., and of thus making his workpeople sober, temperate, healthy, and useful members of the community. As examples of what may be done, I may mention that the Douchy Colliery Company in Northern France has established the following clubs among its workmen: Archers, crossbowmen, gymnasts, philharmonic, and pigeon fanciers; whilst on this side of the Channel we find cricket and football clubs, bands, billiard-tables, and reading-rooms.

CHAPTER XVI.

ACCIDENTS.

I HAVE pointed out in the previous chapter that the dangers threatening the miner and the quarrier are considered sufficient to entitle them to special legislation. It now remains for me to point out what these dangers are, how far the mineral getter's occupation is better or worse than certain other callings, and in what way he most requires protection.

(1) Standard of a Dangerous Occupation.

In the first place what is a 'dangerous' occupation? The 'man in the street' has no hesitation in deciding that mining involves extra-hazardous risks, because from time to time he reads of some appalling colliery explosion with its victims reckoned by scores or by hundreds. Harrowing details rivet the attention of the public, deeds of heroism excite their admiration, the sorrows of the surviving relatives enlist their sympathies, and in these various ways the dangers of mining are impressed upon them. But safety and danger are merely relative terms, and it is necessary to lay down some standard of comparison by which the perils of an occupation can be properly measured. A convenient gauge, applicable to all industries, is the number of persons killed by accident annually per 1000 employed, and judging by the special legislation for miners in all parts of the world, it may be said that a vocation having an annual accident mortality exceeding 1 per 1000 is usually regarded as dangerous. This standard has the advantage of being simple and easily recollected.

(2) Death Rates from Accidents at Mines and Quarries.

The following diagram* (fig. 276) shows graphically the annual death-rates of the mining industry in this country for the last fifty-seven years.

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1900, London, 1901, p. 69. [Cd. 766.] (With the results of the last seven years added to the original diagram, as also in figs. 277–279.)

The figures from which the diagram has been compiled, though the best available, are not so complete as one would like, because the first ten years refer to coal mining alone, the next eleven years to coal and ironstone, whilst only the last thirty-five years comprise all kinds of mining. However, recollecting that 95 per cent. of the British mining population are engaged at collieries, the figures are sufficient for our purpose. The table teaches several useful facts. In the first place, during the early years of the period under consideration 5 persons per 1000 underground workers were killed annually, whereas nowadays the death-rate has fallen to less than $1\frac{1}{2}$. The curve shows a fairly regular drop; occasional big catastrophes, such as Oaks Colliery explosion in 1866 or the Haydock Wood and Abercarn explosions in 1878, cause sudden rises, but the general improvement eventually asserts itself. To sum up matters, mining is now at least three times as safe as it was in the early fifties, and judging by the past one may fairly prophesy still further improvements. Such a result is highly satisfactory, and unquestionably reflects credit upon the British mining engineer.

Figures may be fallacious, and are consequently liable to be viewed with suspicion. I wish therefore to point out that I have been careful to avoid one source of error which too often lessens the value of mining statistics. In estimating the risk of any calling, it is necessary to restrict one's figures to that calling alone. A mistake frequently made in mining statistics is failing to separate the figures which relate to the underground workers from those which relate to the surface hands. The latter have a smaller risk than the former, and if the comparatively safe occupation is mixed up with the comparatively dangerous one, the conclusions are vitiated. The matter is of importance, and I will therefore elucidate it further by a numerical example. Suppose 100,000 persons to be employed at mines in some country and 200 persons to be killed by accident annually; the official statistician will very likely call the death-rate 2 per 1000 per annum; but this is not the mortality-rate of the true *miners*, the *underground* workers. When the statistics come to be dissected, it may turn out that 185 deaths happened from accidents below ground among 80,000 workers, and only 15 from accidents at the surface among 20,000 workers. Consequently the true death-rate of the miners proper will be $\frac{185}{80} = 2{\cdot}31$ per 1000, and that of the surface workers $\frac{15}{20} = 0{\cdot}75$ per 1000.

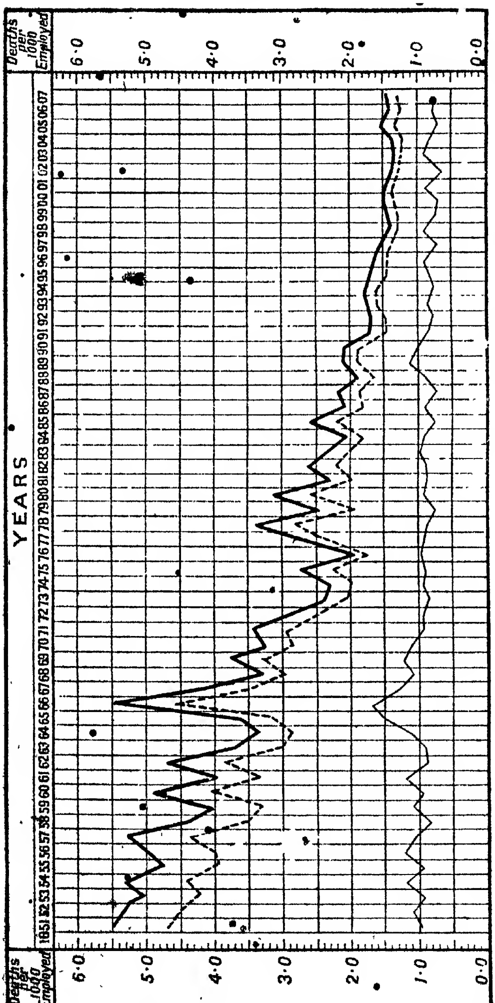


Fig. 276.—Death-rates from accidents per 1000 persons employed at mines of the United Kingdom fr... 1851 to 1907.

—— Below ground. - - - - - - Below and above ground. ——— Above ground

Having dealt with the general mining death-rate of this country I will now devote a few words to the two classes of mines established by statute, viz., mines under the Coal Mines Regulation Acts and mines under the Metalliferous Mines Regulation Acts.

The next diagram (fig. 277) shows their mortality rates separately.

The thick line represents the underground death-rates per 1000 persons at mines under the Coal Mines Regulation Act, the dotted line the corresponding death-rates at mines under the Metalliferous Act. In the last sixteen years, with three slight exceptions, the thick curve has been below the dotted one; in other words, the underground workman at a mine under the Metalliferous Act has a more dangerous occupation than the workman at a mine under the Coal Mines Regulation Act, or, to put matters more plainly, the average collier in this country stands less risk of being killed by accident than the ordinary tin, lead, or copper miner. Under the stringent Coal Mines Acts of 1872 and 1887 the progress along the path of safety has been more marked than under the mild and inadequate Metalliferous Act. No stronger argument can be brought forward for advising its amendment.

Since the Quarries Act came into force in 1894 it has been possible to compile precise statistics concerning the accidents in open pits more than 20 ft. deep. Judging by the diagram* (fig. 278) quarrying, like mining, is a dangerous occupation, if we restrict the term 'quarriers' to the persons actually working *inside* the pits, and refuse to reckon among their number the hosts employed *outside* in brick and cement making, slate-dressing, stonce-utting, etc.

The diagram is somewhat startling, for it shows that the average workman employed in an open pit more than 20 ft. deep is at least as liable to be killed by accident as the average coal or ore miner. Open workings in this country are more dangerous than most people suppose. There can be no better *raison d'être* for a more stringent Quarries Act than the curves in fig. 278.

In the case of mines yielding one mineral such as coal, useful comparisons may be made by referring the number of deaths to the output, or in other words by calculating the number of deaths per million tons raised.

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1902, London, 1903, p. 100. [Cd. 1795.] (With the results of the last five years added to the original diagram.)

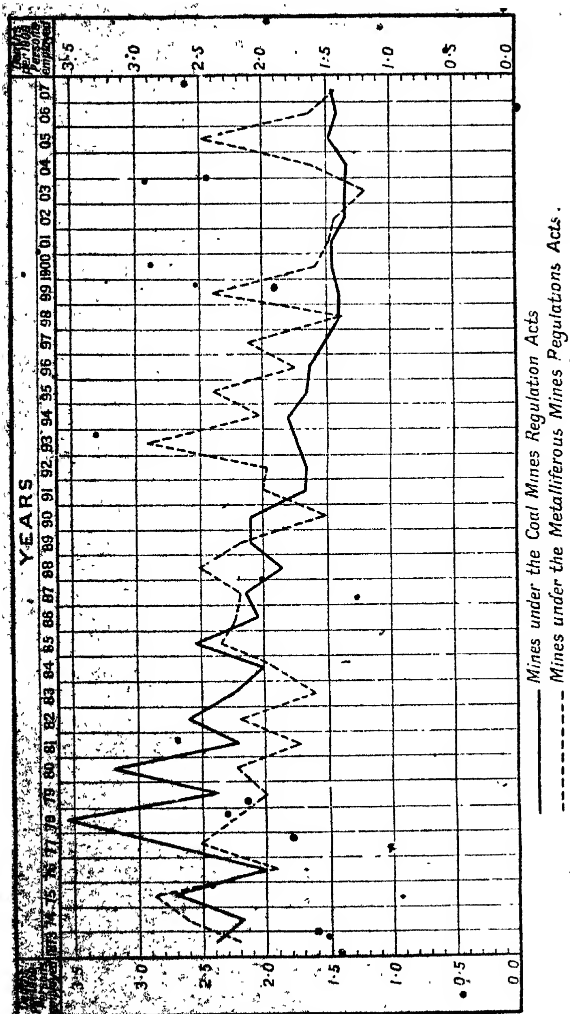


FIG. 277.*—Death-rates from Accidents Underground per 1000 persons employed underground in Mines, under the Coal and Metalliferous Mines Regulation Acts respectively, from 1873 to 1907.

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1902, *p.* 71. (With the results of the last five years added to the original diagram.)

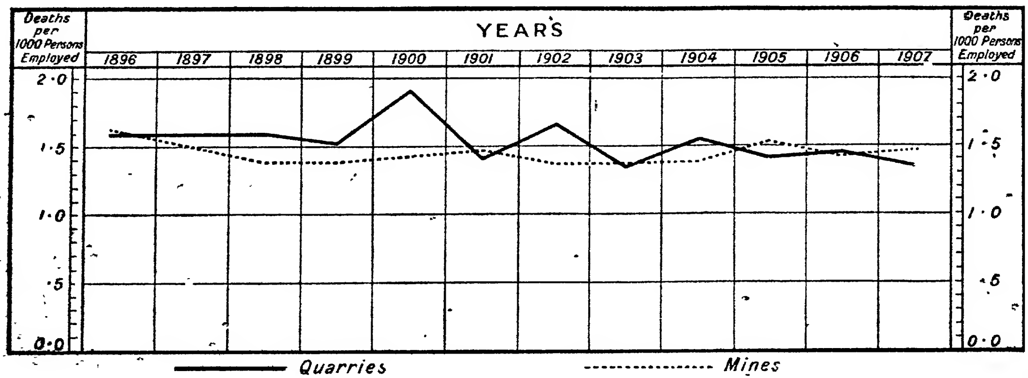


FIG. 278.—Death-rates from accidents to 'inside' workers at quarries under the Quarries Act, and to underground workers at mines under the Mines Acts respectively, 1896 to 1907.

The figures for this country are given in the diagram* (fig. 279).

Thirty years ago every million tons of coal claimed the sacrifice of more than seven lives; nowadays the number of victims is reduced to between four and five. The gradual improvement shown by the curve is eminently satisfactory.

(3) Comparison of Mining and Quarrying with other Industries.

The next question to be discussed is how mining compares with certain other industries as regards safety. Some figures which I prepared for an official report † a few years ago (*see* p. 295) make it plain that the mining and quarrying risk (*see* figs. 277 and 278) is decidedly less than the risk of sailors, and less than that of many railway servants, and of workmen engaged upon large engineering undertakings such as making canals or building bridges.

While in no way wishing to minimize the perils which have to be faced by the miner, it is only fair to point out that there are

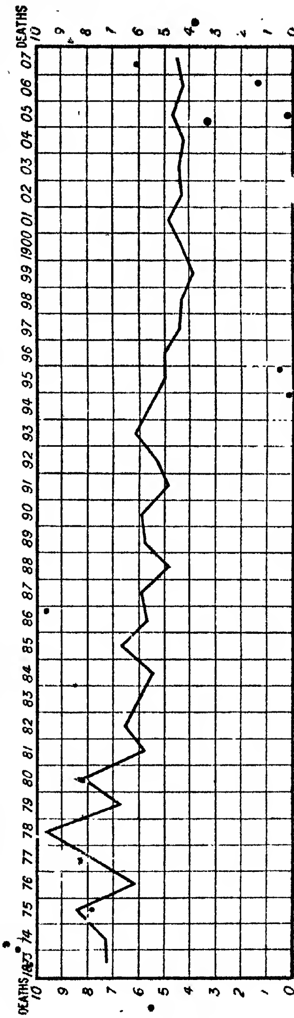


FIG. 279.—Number of deaths per 1,000,000 tons of mineral raised at mines under the Coal Mines Regulation Act, from 1873 to 1907.

* *Ibid.* (as on p. 290), p. 70.

† *Report of the Departmental Committee upon Merionethshire Slate Mines*, London, 1895, p. xx. [Cd. 7692.]

other working men deserving a share of public sympathy and legislative protection. It is to be hoped that at all events the railway servant will soon be feeling the benefit of the new regulations established under the Railway Employment (Prevention of Accidents) Act, 1900.

(4) Classification of Accidents at Mines and Quarries.

Hitherto I have been dealing with the general mortality from accidents; when it is desired to reduce the heavy death-rate which I have pointed out, it becomes necessary to descend into details in order to determine which classes of accidents are most to be feared. The case may be compared to that of a country with a heavy mortality from various diseases. The health department will be anxious to find out what proportion of the deaths is due to each class of disease, in order to settle into what channel it should particularly direct its energies.

Mining and quarrying accidents must therefore be classified according to cause.

The scheme adopted by the British Inspectors of Mines first separates the underground accidents from the surface accidents, and then classifies the former under four main headings. We therefore have :—

Accidents at Mines.

Underground . .	Explosions of fire-damp or coal dust. Falls of ground. Shaft accidents. Miscellaneous accidents.
Above ground.	

Occupational Risks.

Industry.	Years to which the Figures relate (in all cases inclusive).	Average Annual Death-rate from Accidents per 1000 Persons Employed.
Quarrying.		
Open slate quarries, Carnarvonshire	1883–1892	1·53
Penrhyn slate quarry, near Bangor	,, ,,	0·76
Dinorwic slate quarry, near Llanberis	,, ,,	0·71
Open slate quarries in Carnarvonshire, omitting Dinorwic and Penrhyn	,, ,,	2·82
Stone quarries, Carnarvonshire	,, ,,	1·30
Engineering.		
Construction of Manchester Ship Canal	1887–1892	2·48
Construction of Tower Bridge, London	1886–1894	2·90
Railways.		
Railway servants of the United Kingdom (accidents in which the movement of vehicles was concerned)	1870, 1873, 1877, and 1880–1892	1·48
(*a*) Brakesmen and goods-guards	1884–1893	5·27
(*b*) Permanent-way men	,, ,,	2·87
(*c*) Engine-drivers	,, ,,	1·60
(*d*) Porters	1887–1893	1·49
(*e*) Shunters	,, ,,	5·41
(*f*) Passenger-guards	1884–1893	1·02
Average of the six occupations *a*, *b*, *c*, *d*, *e*, *f*,	,, ,,	2·27
All the railway servants of the United States	Year ended June 30, 1890	3·27
Railway servants in the United States engaged directly in handling trains, viz., engine-drivers, firemen, guards, and other trainmen	Year ended June 30, 1890	9·52
Shipping.		
Crews of British merchant ships registered in the United Kingdom	1871–1880	13·45
,, ,, ,, ,, ,, ,,	1881–1890	11·04
,, ,, ,, ,, ,, ,,	1891	8·67
,, ,, ,, ,, ,, ,,	1892	8·36

The next diagrams (fig. 280*) are of interest in showing how each class has contributed in the past to swell the total death-roll. Whether we take the full half-century or any one particular decade, we find that by far the most formidable enemy of the miner is the 'fall of ground.' Granted that an occasional explosion may claim scores of victims at once, the constantly recurring single fatalities from falls add up at the end of the year

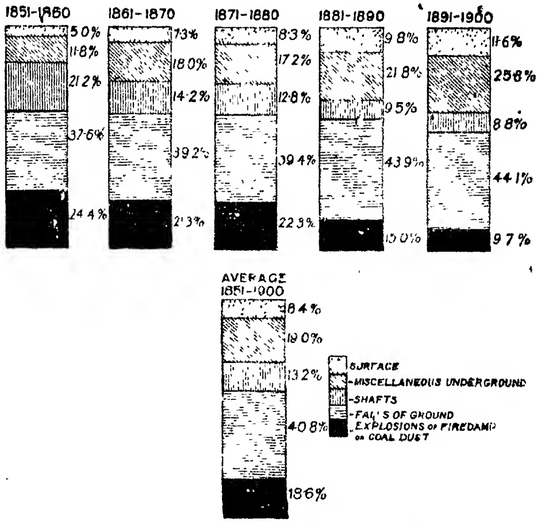


FIG. 280.—Proportion of deaths from different classes of accidents.†

to a far higher total. This is the most important lesson to be learnt from the statistics of mining accidents.

As we pass the various decades in review, the waning importance of explosions is very striking and also the growing safety of shafts in spite of their increasing depth.

On the other hand, surprise may be expressed at the larger proportion in later years of the accidents classed as 'Miscellaneous,'

* C. Le. Neve Foster *Mines and Quarries: General Report and Statistics for* 1900, London, 1901 [Cd. 766]. p. 74.

† From 1851 to 1860 the statistics relate to coal mines only.
,, 1861 ,, 1872 ,, ,, ,, ,, ,, coal and ironstone mines only.
,, 1873 ,, 1900 ,, ,, ,, ,, ,, all mines.

which include the numerous casualties from haulage. The reason is not far to seek. Larger areas are now worked from a given pair of shafts and the average distance between the working face and the pit bottom is consequently greater, and the traffic is carried on mechanically instead of by hand.

The increase in the proportion of the surface accidents may be explained in a similar manner. Far more work is done nowadays by mechanical means in preparing coal for the market than formerly, and the introduction of machinery has brought a factory risk into a domain where formerly there were only workshop dangers.

The same story is told in a somewhat different way by fig. 281.*

The classification of mining accidents adopted for the United Kingdom is shown by the following table (p. 299), which gives the actual number of deaths due to each cause for 1900, 1901, and 1902.

Quarry accidents are divided officially into four main classes, and each class is subdivided according to the table on p. 300, which gives the results for the three years 1900, 1901, and 1902.

(5) Commonest Dangers at Mines and Quarries.

As already pointed out when dealing with the main headings, it is evident that the worst sore afflicting the miner is the 'fall of ground.' No effort should be spared to prevent accidents from this source, and it may be hoped that the new Special Rules which require props to be put in at stated intervals, regardless of any apparent firmness of the roof, will in due time bear valuable fruit.

Next in grievousness are the haulage accidents. Much can be done to reduce their number by preventing the mechanical haulage roads from being used as the ordinary travelling roads of the pit's crew, or, where it is commercially out of the question to provide separate roads, by fencing off a portion of the road for travelling purposes.

The statistics show that the risk of over-winding is greatly exaggerated by the outside public, and bear testimony to the care and skill of the British engineman.

Although the quarryman is threatened, not by falls of roof like the miner, but only by falls of side, it is evident from the last table that this class of accident is the one most to be dreaded. An

* C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for* 1902, London, 1903 [Cd. 1795], Opp. p. 68.

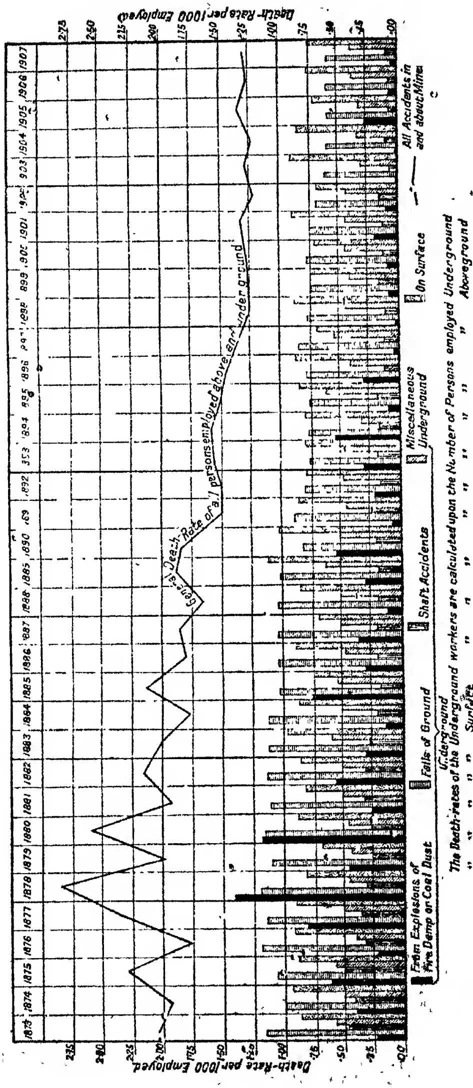


FIG. 281.—Death-rates from various causes of accidents in and about all mines of the United Kingdom from 1873 to 1907.

Deaths from Accidents at all the Mines in the United Kingdom for the Three Years 1900, 1901 and 1902.

Place or Cause of Accident.	Number of Deaths.		
	1900.	1901.	1902.
Explosions of fire-damp or coal-dust	45	125	63
Falls of ground	509	494	467
Shaft accidents—			
Overwinding	5	1	4
Ropes or chains breaking	5	1	11
Whilst ascending or descending by machinery	20	22	21
Falling into shaft from surface	6	5	4
Things falling from surface	3	2	4
Falling from part way down	25	25	32
Things falling from part way down	4	7	8
Miscellaneous	18	13	21
Total	86	79	105
Miscellaneous underground—			
By explosives	31	22	22
Suffocation by natural gases	8	4	9
By underground fires	.	[illegible]	7
Irruptions of water	8	...	4
Haulage*—			
Ropes or chains breaking	16	20	18
In other ways (run over by trams and tubs, etc.)	168	172	187
By machinery	15	12	10
Sundries	45	42	41
Total	291	280	298
Total underground	931	978	933
On surface—			
By machinery	20	13	14
Boiler explosions	4	1	...
Railways, sidings, or tramways	55	103	66
Miscellaneous	40	36	40
Total on Surface	119	153	120
Gross Total	1,050	1,131	1,053

* In the "Inspectors' Reports" for 1902, haulage accidents are classified as follows: (*a*) Ropes or chains breaking; (*b*) Run over by trams and tubs; (*c*) Other haulage accidents. As this classification differs from that adopted in previous years, it has been necessary in this table to put (*b*) and (*c*) together. Of the 187 deaths in 1902 no less than 112 are placed under the heading (*b*).

Deaths from Accidents in and about Quarries more than 20 ft. deep in the United Kingdom during the Years 1900, 1901 *and* 1902.

Place or Cause of Accident.	Number of Deaths. 1900.	1901.	1902.
Inside the quarries (*i.e.*, inside the actual pits, holes, or excavations).			
Falls of ground—			
From beyond the person's own working place	16	15	14
From the person's own working place	37	24	30
Total	53	39	44
By blasting—			
While charging or tamping	6	8	9
From stones projected by shots, when persons had not taken sufficient shelter	3	3	4
From miss-fires		2	1
Miscellaneous	4	2	2
Total	13	15	16
During ascent or descent—			
Falling from paths, steps, or ladders	3	3	3
When ascending or descending by machinery	1	.	...
Miscellaneous	...	.	...
Total	4	3	3
Miscellaneous—			
Ropes or chains breaking	3	1	1
Machinery	4	...	5
Boiler explosions	...	1	...
Inclined and engine planes	...	1	1
Railways, sidings, or tramways	11	4	7
Falling from ledges	12	10	9
Sundries	15	12	17
Total	45	29	40
Total inside quarries	115	86	103
Outside the quarries—			
Machinery	2	4	6
Boiler explosions	...	...	...
Inclined and engine planes	2	1	...
Railways, sidings, or tramways	3	6	7
Miscellaneous	5	1	3
Total outside quarries	12	12	16
Gross Total	127	98	119

endeavour is made in the British statistics to draw a distinction between falls coming from the man's own working place, which it is his business under the Special Rules to inspect, and those coming from elsewhere. Whilst the actual getter may fairly be expected to share with the agent the responsibility of seeing to the safety of the working face, the casual passer, the loader, the trammer, and the dresser have a right to claim that the employer shall protect them from falling stones.

Blasting accidents are frequent. Their number might certainly be reduced if quarry-owners would enforce better discipline, because injuries or deaths often result from stones projected by shots, which would have had no harmful effects if workmen had retired to the shelters specially erected for them in conformity with the Special Rules.

It is beyond the scope of an elementary text-book to deal with the means of preventing every class of mining and quarrying accident; the subject is one requiring a lengthy treatise for itself, and my object at present is simply to act as a finger-post to the student, and point out a road which it will be his duty to travel later on.

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